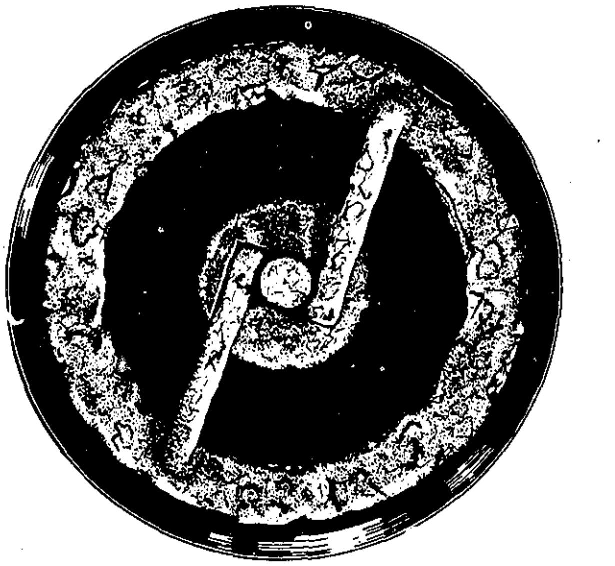


FIGURE 4–52. Carbon-fouled spark plug.

of the engine and the turbulence in the combustion chamber are slight. At higher engine speeds and powers, however, the soot is swept out and does not condense out of the charge in the combustion chamber.

Even though the idling fuel/air mixture is correct, there is a tendency for oil to be drawn into the cylinder past the piston rings, valve guides, and impeller shaft oil seal rings. At low engine speeds, the oil combines with the soot in the cylinder to form a solid which is capable of shorting out the spark plug.

Spark plugs that are wet or covered with lubricating oil are usually grounded out during the engine start. In some cases these plugs may clear up and operate properly after a short period of engine operation.

Engine oil that has been in service for any length of time will hold in suspension minute carbon particles that are capable of conducting an electric current. Thus, a spark plug will not arc the gap between the electrodes when the plug is full of oil. Instead, the high-voltage impulse flows through the oil from one electrode to the other without a spark just as surely as though a wire conductor were placed between the two electrodes. Combustion in the affected cylinder does not occur until, at a higher r.p.m., increased airflow has carried away the excess oil. Then, when intermittent firing starts, combustion assists in emitting the remaining oil. In a few seconds the engine is running clean with white fumes of evaporating and burning oil coming from the exhaust.

Lead Fouling of Spark Plugs

Lead fouling of aviation spark plugs is a condition likely to occur in any engine using "leaded fuels." Lead is added to aviation fuel to improve its antiknock qualities. The lead, however, has the undesirable effect of forming lead oxide during combustion. This lead oxide forms as a solid with varying degrees of hardness and consistency. Lead deposits on combustion chamber surfaces are good electrical conductors at high temperatures and cause misfiring. At low temperatures the same deposits may be good insulators. In either case, lead formations on aircraft spark plugs, such as shown in figure 4–53, prevent their normal operation. To minimize the formation of lead deposits, ethylene dibromide is added to the fuel as a scavenging agent which combines with the lead during combustion.

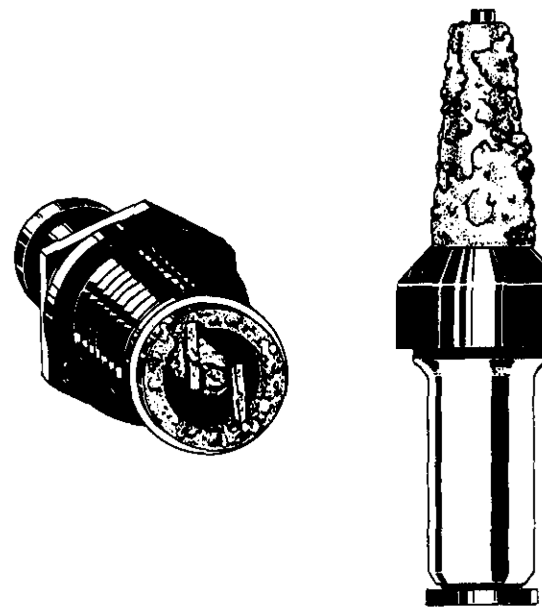


FIGURE 4–53. Lead-fouled spark plug.

Lead fouling may occur at any power setting, but perhaps the power setting most conducive to lead fouling is cruising with lean mixtures. At this power, the cylinder head temperature is relatively low and there is an excess of oxygen over that needed to consume all the fuel in the fuel/air mixture. Oxygen, when hot, is very active and aggressive; and when all the fuel has been consumed, some of the excess oxygen unites with some of the lead and some of the scavenger agent to form oxygen compounds of lead or bromine or both. Some of these undesirable lead compounds solidify and build up in layers as they contact the relatively cool cylinder walls and spark plugs.

Although lead fouling may occur at any power setting, experience indicates that the lead buildup is generally confined to a specific combustion temperature range, and combustion temperatures higher or lower than this specific range minimize the lead-fouling tendency. If lead fouling is detected before the spark plugs become completely fouled, the lead can normally be eliminated or reduced by either a sharp rise or a sharp decrease in combustion temperature. This imposes a thermal shock on cylinder parts, causing them to expand or contract. Since there is a different rate of expansion between deposits and metal parts on which they form, the deposits chip off or are loosened and then scavenged from the combustion chamber by the exhaust or are burned in the combustion process.

Several methods of producing thermal shock to cylinder parts are used. The method used, of course, depends on the accessory equipment installed on the engine. A sharp rise in combustion temperatures can be obtained on all engines by operating them at full takeoff power for approximately 1 minute. When using this method to eliminate fouling, the propeller control must be placed in low pitch (high r.p.m.) and the throttle advanced slowly to produce takeoff r.p.m. and manifold pressure. Slow movement of the throttle control provides reasonable freedom from backfiring in the affected cylinders during the application of power.

Another method of producing thermal shock is the use of excessively rich fuel/air mixtures. This method suddenly cools the combustion chamber because the excess fuel does not contribute to combustion; instead, it absorbs heat from the combustion area. Some carburetor installations use two-position manual mixture controls, which provide a lean mixture setting for cruising economy and a richer mixture setting for all powers above cruising. Neither manual mixture control setting in this type of configuration is capable of producing an excessively rich fuel/air mixture. Even when the engine is operated in auto-rich at powers where an auto-lean setting would be entirely satisfactory, the mixture is not rich enough.

Therefore, to obtain a richer fuel/air mixture than the carburetor is capable of delivering, the primer system is used to supplement the normal fuel flow. Enrichment and thermal shock can be effected by the primer at all engine speeds, but its effectiveness in removing lead decreases as fuel metering through normal channels increases. The reason for this is that all electric primers deliver a nearly constant fuel flow at all engine speeds and powers in a like period of time. Therefore, comparatively speaking, the primer will enrich the lean mixtures of low engine speeds far more than it would the richer mixtures accompanying higher engine speeds.

Regardless of the power setting at which primer purging is used, the primer should be used continuously for a 2-minute interval. If normal engine operation is not restored after a 2-minute interval, it may be necessary to repeat the process several times. Some priming systems prime only the cylinders above the horizontal centerline of the engine; in which case, only those cylinders receiving the priming charge can be purged.

On engines equipped with water injection, combustion temperature can be sharply decreased by manual operation of the water injection system. Water injection is normally reserved for high-power operation; but when it is used for purging purposes, the system is most effective when activated in the cruising range, it is accompanied by a momentary power loss. This power loss can be traced to the following factors. First of all, the derichment jet is not metering the fuel in the cruising range. Hence, when the derichment valve is closed by the water injection system, there is no decrease in fuel flow from the carburetor. Secondly, when the water regulator first starts to meter, it meters fuel that was backed up into the water transfer line during normal "dry" operation. This fuel, plus the unchanged fuel flow from the carburetor, produces an overrich mixture, temporarily flooding the engine. As soon as this fuel is consumed by the engine, engine power returns, but to a value slightly less than was obtained before water injection. When water injection is used to lower combustion temperatures, it should be limited to a short (approximately 1-minute) interval, even though several intervals may be necessary to free the cylinders of the lead deposit.

Some water injection system installations are considered automatic; that is, the operator has no control over the power at which the system will "cut in." These systems start injecting water automatically at some predetermined manifold pressure if the water pump has been turned on. When these systems are used for lead purging, the full benefit of water injection cannot be obtained because at high-power settings where the automatic system starts to operate, more heat is generated by the engine, the fuel/air ratio is leaned, and the combustion temperature cannot be lowered as much. Regardless of how lead is removed from cylinder parts, whether it is by high-power operation, by use of the primer, or by use of the water injection system, the corrective action must be initiated before the spark plugs are completely shorted or fouled out.

Graphite Fouling of Spark Plugs

As a result of careless and excessive application of thread lubricant to the spark plug, the lubricant will flow over the electrodes and cause shorting. Shorting occurs because graphite is a good electrical conductor. The elimination of service difficulties caused by graphite is up to the aviation mechanics. Use care when applying the lubricant to make certain that smeared fingers, rags, or brushes do not contact the electrodes or any part of the ignition system except the spark plug threads. Practically no success has been experienced in trying to burn off or dislodge the thread lubricant.

Gap Erosion of Spark Plugs

Erosion of the electrodes takes place in all aircraft spark plugs as the spark jumps the airgap between the electrodes. (See figure 4–54.)

The spark carries with it a portion of the electrode, part of which is deposited on the other electrode, and the remainder is blown off in the combustion chamber. As the airgap is enlarged by erosion, the resistance that the spark must overcome in jumping the airgap also increases. This means that the magneto must produce a higher voltage to overcome the higher resistance. With higher voltages in the ignition system, a greater tendency exists for the spark to discharge at some weak insulation point in the ignition harness. Since the resistance of an airgap also increases as the pressure in the engine cylinder increases, a double danger exists at takeoff and during sudden acceleration with enlarged airgaps. Insulation breakdown, premature flash-over, and carbon tracking result in misfiring of the spark plug, and go hand in hand with excessive spark plug gap. Wide gap settings also raise the "coming in speed" of a magneto and therefore cause hard starting.

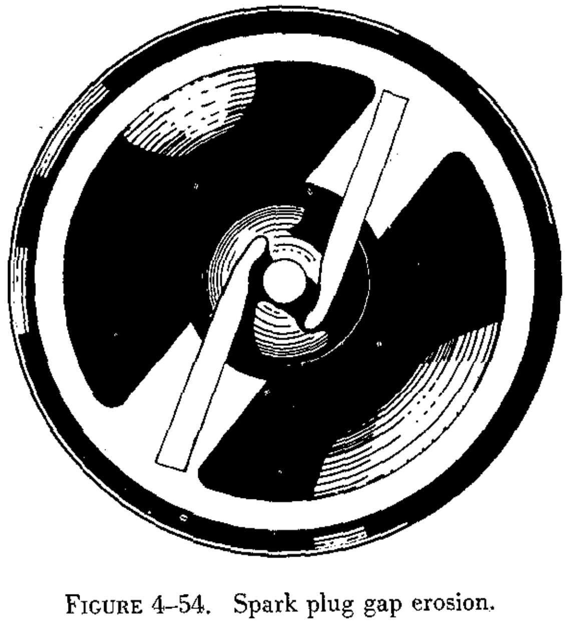


FIGURE 4–54. Spark plug gap erosion.

Spark plug manufacturers have partially overcome the problem of gap erosion by using a hermetically sealed resistor in the center electrode of some spark plugs. This added resistance in the high-tension circuit reduces the peak current at the instant of firing. This reduced current flow aids in preventing metal disintegration in the electrodes. Also, due to the high erosion rate of steel or any of its known alloys, spark plug manufacturers are using tungsten or an alloy of nickel for their massive electrode plugs and platinum plating for their fine wire electrode plugs.

Spark Plug Removal

Spark plugs should be removed for inspection and servicing at the intervals recommended by the manufacturer. Since the rate of gap erosion varies with different operating conditions, engine models, and type of spark plug, engine malfunction traceable to faulty spark plugs may occur before the regular servicing interval is reached. Normally, in such cases, only the faulty plugs are replaced.

Careful handling of the used and replacement plugs during installation and removal of spark plugs from an engine cannot be overemphasized, since spark plugs can be easily damaged. To prevent damage, spark plugs should always be handled individually, and new and reconditioned plugs should be stored in separate cartons. A common method of storage is illustrated in figure 4–55. This is a drilled tray, which prevents the plugs from bumping against one another and damaging the fragile insulators and threads. If a plug is dropped on the floor or other hard surface, it should not be installed in an engine, since the shock of impact usually causes small, invisible cracks in the insulators. The plug should be tested under controlled

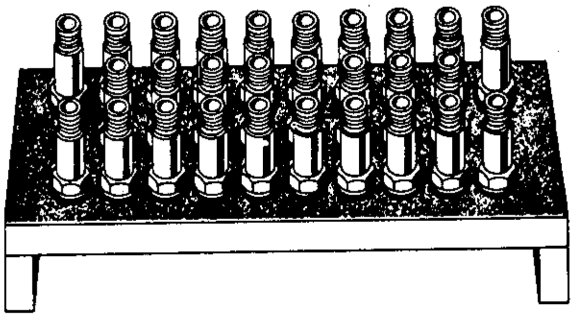


FIGURE 4–55. Spark plug tray.

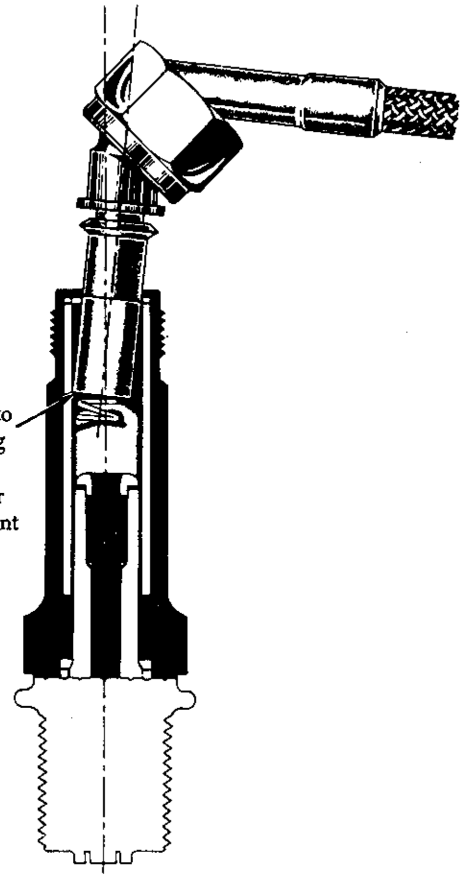


FIGURE 4–56. Improper lead removal technique.

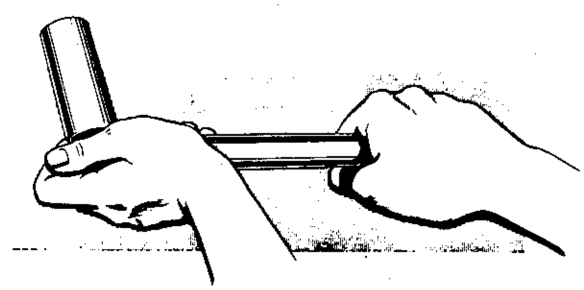


FIGURE 4–57. Proper spark plug removal technique.

pressure conditions before use.

Before a spark plug can be removed, the ignition harness lead must be disconnected. Using the special spark plug coupling elbow wrench, loosen and remove the spark plug to elbow coupling nut from the spark plug. Take care to pull the lead straight out and in line with the centerline of the plug barrel. If a side load is applied, as shown in figure 4–56, damage to the barrel insulator and the ceramic lead terminal may result. If the lead cannot be removed easily in this manner, the neoprene collar may be stuck to the shielding barrel. Break loose the neoprene collar by twisting the collar as though it were a nut being unscrewed from a bolt.

After the lead has been disconnected, select the proper size deep socket for spark plug removal. Apply a steady pressure with one hand on the hinge handle holding the socket in alignment with the other hand. Failure to hold the socket in correct alignment, as shown in figure 4–57, will cause the socket to cock to one side and damage the spark plug.

In the course of engine operation, carbon and other products of combustion will be deposited across the spark plug and cylinder, and some carbon may even penetrate the lower threads of the shell. As a result, a high torque is generally required to break the spark plug loose. This factor imposes a shearing load on the shell section of the plug; and if the load is great enough, the plug may break off, leaving the shell section in the cylinder spark plug hole.

Inspection and Maintenance Prior to Installation

Before installing new or reconditioned spark plugs in the engine cylinders, clean the spark plug bushings or Heli-Coil inserts.

Brass or stainless steel spark plug bushings are usually cleaned with a spark plug bushing cleanout tap. Before inserting the cleanout tap in the spark plug hole, fill the flutes of the tap (channels between threads) with clean grease to prevent hard carbon or other material removed by the tap from dropping into the inside of the cylinder. Align the tap with the bushing threads by sight where possible, and start the tap by hand until there is no possibility of the tap being cross-threaded in the bushing. To start the tap on some installations where the spark plug hole is located deeper than can be reached by a clenched hand, it may be necessary to use a short length of hose slipped over the square end of the tap to act as an extension. When screwing the tap into the bushing, be sure that the full tap cutting thread reaches the bottom thread of the bushing. This will remove carbon deposits from the bushing threads without removing bushing metal, unless the pitch diameter of the threads has contracted as the result of shrinkage or some other unusual condition. If, during the thread-cleaning process, the bushing is found to be loose or is loosened in the cylinder or the threads are cross-threaded or otherwise seriously damaged, replace the cylinder.

Spark plug Heli-Coil inserts are cleaned with a round wire brush, preferably one having a diameter slightly larger than the diameter of the spark plug hole. A brush considerably larger than the hole may cause removal of material from the Heli-Coil proper or from the cylinder head surrounding the insert. Also, the brush should not disintegrate with use, allowing wire bristles to fall into the cylinder. Clean the insert by carefully rotating the wire brush with a power tool. When using the power brush, be careful that no material is removed from the spark plug gasket seating surface, since this may cause a change in the spark plug's heat range, combustion leakage, and eventual cylinder damage. Never clean the Heli-Coil inserts with a cleaning tap, since permanent damage to the insert will result. If a Heli-Coil insert is damaged as a result of normal operation or while cleaning it, replace it according to the applicable manufacturer's instructions.

Using a lint-free rag and cleaning solvent, wipe the spark plug gasket seating surface of the cylinder to eliminate the possibility of dirt or grease being accidentally deposited on the spark plug electrodes at the time of installation.

Before the new or reconditioned plugs are installed, they must be inspected for each of the following conditions:

(1) Be sure the plug is of the approved type, as indicated by the applicable manufacturer's instructions.
(2) Check for evidence of rust-preventive compound on the spark plug exterior and core insulator and on the inside of the shielding barrel. Rust-preventive compound accumulations are removed by washing the plug with a brush and cleaning solvent. It must then be dried with a dry air blast.
(3) Check both ends of the plug for nicked or cracked threads and any indication of cracks in the nose insulator.
(4) Inspect the inside of the shielding barrel for cracks in the barrel insulator, and the center electrode contact for rust and foreign material which might cause poor electrical contact.
(5) Inspect the spark plug gasket. A gasket that has been excessively flattened, scarred, dented, or distorted by previous use must *not* be used. When the thermocouple gasket is used, do not use an additional gasket.

The gap setting should be checked with a round wire thickness gage, as shown in figure 4–58. A flat type gage will give an incorrect clearance indication because the massive ground electrodes are contoured to the shape of the round center electrode. When using the wire thickness gage, insert the gage in each gap parallel to the centerline of the center electrode. If the gage is tilted slightly, the indication will be incorrect. Do not install a plug that does not have an airgap within the specified clearance range.

Spark Plug Installation

Prior to spark plug installation, carefully coat the first two or three threads from the electrode end of the shell with a graphite base antiseize compound. Prior to application, stir the antiseize compound to ensure thorough mixing. When applying the antiseize compound to the threads, be extremely careful

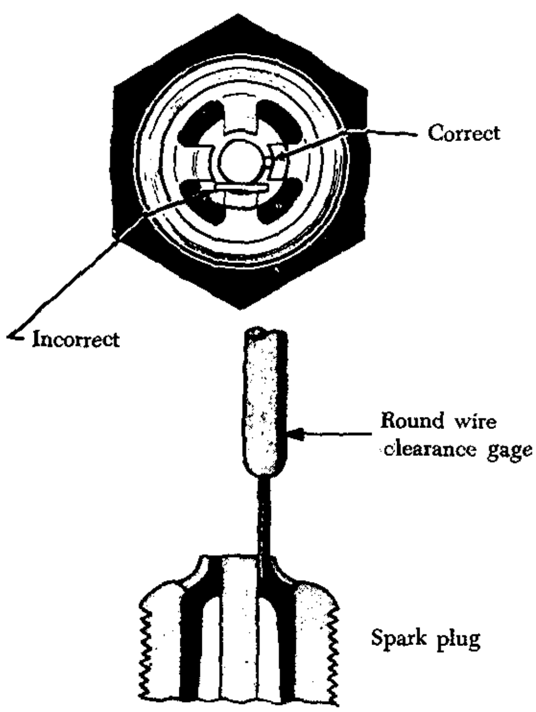


FIGURE 4–58. Use of a gap-measuring gage.

that none of the compound gets on the ground or center electrodes or on the nose of the plug, where it can spread to the ground or center electrode during installation. This precaution is mentioned because the graphite in the compound is an excellent electrical conductor and could cause permanent fouling.

To install a spark plug, start it into the cylinder without using a wrench of any kind, and turn it until the spark plug is seated on the gasket. If the plug can be screwed into the cylinder with comparative ease, using the fingers, this indicates good, clean threads. In this case, only a small additional tightening torque will be needed to compress the gasket to form a gastight seal. If, on the other hand, a high torque is needed to install the plug, dirty or damaged threads on either the plug or plug bushing are indicated. The use of excessive torque might compress the gasket out of shape and distort and stretch the plug shell to a point where breakage would result during the next removal or installation. Shell stretching occurs as excessive torque continues to screw the lower end of the shell into the cylinder after the upper end has been stopped by the gasket shoulder. As the shell stretches (figure 4–59), the seal between the shell and core insulator is opened, creating a loss of gas tightness or damage to the core insulator. After a spark plug has been seated with the fingers, use a torque wrench and tighten to the specified torque.

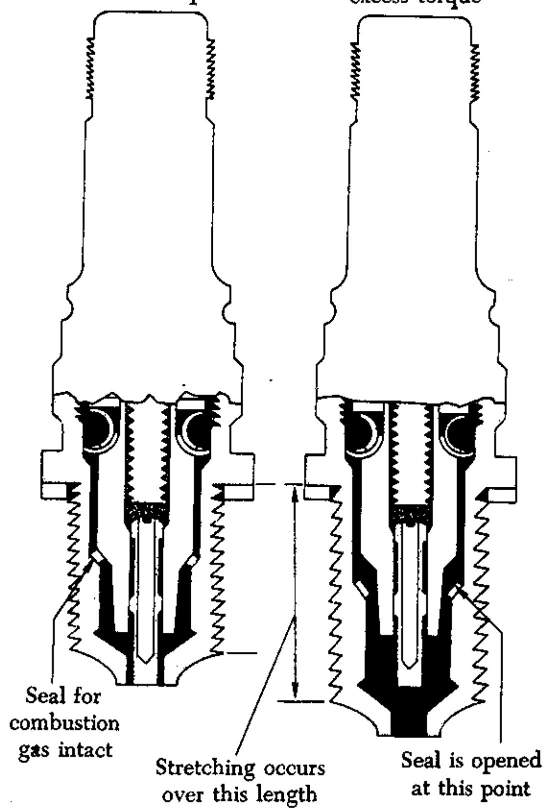


FIGURE 4–59. Effect of excessive torque in installing a spark plug.

Spark Plug Lead Installation

Before installing the spark plug lead, carefully wipe the terminal sleeve (sometimes referred to as "cigarette") and the integral seal with a cloth moistened with acetone, MEK, or an approved solvent. After the plug lead is cleaned, inspect it for cracks and scratches. If the terminal sleeve is damaged or heavily stained, replace it.

Application of a light coating of an insulating material to the outer surface of the terminal sleeve and also filling the space occupied by the contact spring is sometimes recommended. Such insulating material, by occupying the space in the electrical contact area of the shielding barrel, prevents moisture from entering the contact area and shorting the spark plug. Some manufacturers recommend the use of such insulating compounds only when moisture in the ignition system becomes a problem, and others have discontinued entirely the use of such materials.

After inspection of the spark plug lead, slip the lead into the shielding barrel of the plug with care. Then tighten the spark plug coupling elbow nut with the proper tool. Most manufacturers' instructions specify the use of a tool designed to help prevent an overtorque condition. After the coupling nut is tightened, avoid checking for tightness by twisting the body of the elbow.

After all plugs have been installed, torqued, and the leads properly installed, start the engine and perform a complete ignition system operational check.

Breaker Point Inspection

Inspection of the magneto consists essentially of a periodic breaker point and dielectric inspection. After the magneto has been inspected for security of mounting, remove the magneto cover, or breaker cover, and check the cam for proper lubrication. Under normal conditions there is usually ample oil in the felt oiler pad of the cam follower to keep the cam lubricated between overhaul periods. However, during the regular routine inspection, examine the felt pad on the cam follower to be sure it contains sufficient oil for cam lubrication. Make this check by pressing the thumbnail against the oiler pad. If oil appears on the thumbnail, the pad contains sufficient oil for cam lubrication. If there is no evidence of oil on the fingernail, apply one drop of a light aircraft engine oil to the bottom felt pad and one drop to the upper felt pad of the follower assembly, as shown in figure 4–60.

After application, allow at least 15 minutes for the felt to absorb the oil. At the end of 15 minutes, blot off any excess oil with a clean, lint-free cloth. During this operation, or any time the magneto cover is off, use extreme care to keep the breaker compartment free of oil, grease, or engine cleaning solvents, since each of these has an adhesiveness which collects dirt and grime that could foul an otherwise good set of breaker contact points.

After the felt oiler pad has been inspected, serviced, and found to be satisfactory, visually inspect the breaker contacts for any condition that may interfere with proper operation of the magneto. If the inspection reveals an oily or gummy substance on the sides of the contacts, swab the contacts with a flexible wiper, such as a pipe cleaner dipped in acetone or some other approved solvent. By forming a hook on the end of the wiper, ready access can be gained to the back side of the contacts.

To clean the contact mating surfaces, force open the breaker points enough to admit a small swab. Whether spreading the points for purposes of cleaning or checking the surfaces for condition, always apply the opening force at the outer end of the mainspring and never spread the contacts more than one-sixteenth (0.0625) in. If the contacts are spread wider than recommended, the mainspring (the spring carrying the movable contact point) is likely to take a permanent set. If the mainspring takes a permanent set, the movable contact point loses some of its closing tension and the points will then either "bounce" or "float," preventing the normal induction buildup of the magneto.

A swab can be made by wrapping a piece of linen tape or a small piece of lint-free cloth over one of the leaves of a clearance gage and dipping the swab in an approved solvent. Then pass the swab between the carefully separated contact surfaces until the surfaces are clean. During this entire operation take care that drops of solvent do not fall on lubricated parts, such as the cam, follower block, or felt oiler pad.

To inspect the breaker contact surfaces, it is necessary to know what a normal operating set of contacts looks like, what surface condition is considered as permissible wear, and what surface condition is cause for dressing or replacement. The probable cause of an abnormal surface condition can also be determined from the contact appearance. The normal contact surface (figure 4–61) has a dull gray, sandblasted (almost rough) appearance over the area where electrical contact is made. This gray, sandblasted appearance indicates that the points have worn in and have mated to each other and are providing the best possible electrical contact.

This is not meant to imply that this is the only acceptable contact surface condition. Slight, smooth-surfaced irregularities, without deep pits or high peaks, such as shown in figure 4–62, are considered normal wear and are not cause for dressing or replacement.

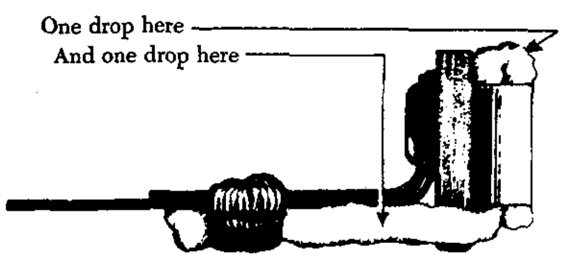


FIGURE 4–60. Oiling the cam follower.

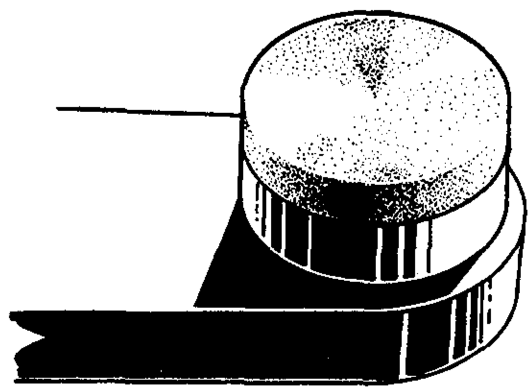


FIGURE 4–61. Normal contact surface.

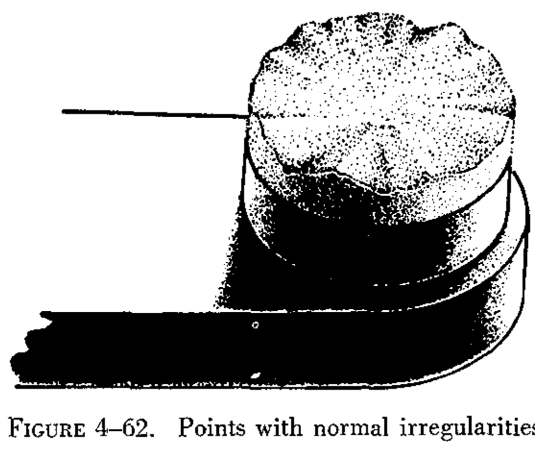


FIGURE 4–62. Points with normal irregularities.

However, when wear advances to a point where the slight, smooth irregularities develop into well-defined peaks extending noticeably above the surrounding surface, as illustrated in figure 4–63, the breaker contacts must be dressed or replaced.

Unfortunately, when a peak forms on one contact, the mating contact will have a corresponding pit or hole. This pit is more troublesome than the peak because it penetrates the platinum pad of the contact surface. It is sometimes difficult to judge whether a contact surface is pitted deeply enough to require dressing, because in the final analysis this depends on how much of the original platinum is left on the contact surface. The danger arises from the possibility that the platinum pad may already be thin as a result of long service life and previous dressings. At overhaul facilities, a gage is used to measure the remaining thickness of the pad, and no difficulty in determining the condition of the pad exists. But at line maintenance activities, this gage is generally unavailable. Therefore, if the peak is quite high or the pit quite deep, do not dress these contacts; instead, remove and replace them with a new or reconditioned assembly. A comparison between figures 4–62 and 4–63 will help to draw the line between "minor irregularities" and "well-defined peaks."

Some examples of possible breaker contact surface conditions are illustrated in figure 4–64. Item A illustrates an example of erosion or wear called "frosting." This condition results from an open-circuited condenser and is easily recognized by the coarse, crystalline surface and the black "sooty" appearance of the sides of the points. The lack of effective condenser action results in an arc of intense heat being formed each time the points open. This, together with the oxygen in the air, rapidly oxidizes and erodes the platinum surface of the points, producing the coarse, crystalline, or frosted appearance. Properly operating points have a fine-grained, frosted, or silvery appearance and should not be confused with the coarse-grained and sooty point caused by faulty condenser action.

Items B and C of figure 4–64 illustrate badly pitted points. These points are identified by a fairly even contact edge (in the early stage) and minute pits or pocks in or near the center of the contact surface with a general overall smoky appearance. In more advanced stages, the pit may develop into a large, jagged crater, and eventually the entire contact surface will take on a burned, black, and crumpled appearance. Pitted points, as a general rule, are caused by dirt and impurities on the contact surfaces. If points are excessively pitted, a new or reconditioned breaker assembly must be installed.

Item D of figure 4–64 illustrates a "crowned" point and can be readily identified by the concave center and a convex rim on the contact surface. This condition results from improper dressing, as may be the case when an attempt is made to dress points while they are still installed in the magneto. In addition to an uneven or unsquare surface, the tiny particles of foreign material and metal that

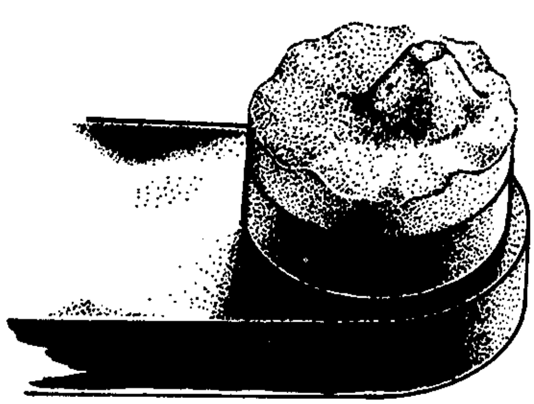


FIGURE 4–63. Points with well-defined peaks.

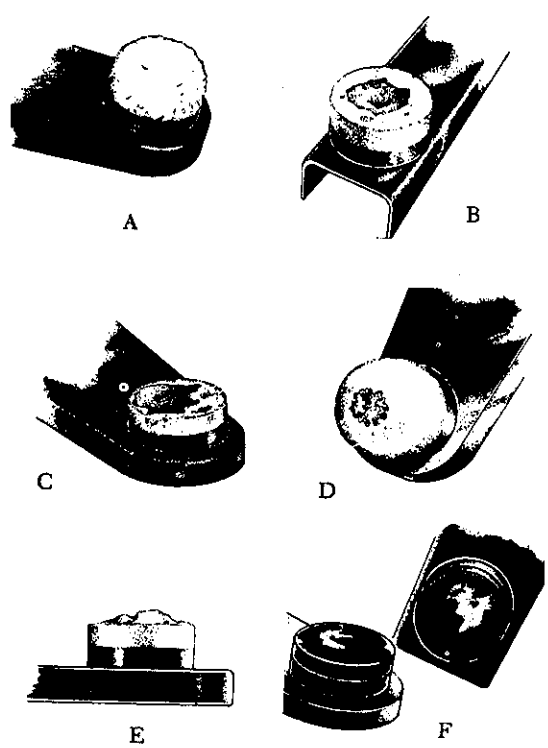


FIGURE 4–64. Examples of contact surface condition.

remain between the points after the dressing operation fuse and cause uneven burning of the inner contact surface. This burning differs from "frosting" in that a smaller arc produces less heat and less oxidation. In this instance the rate of burning is more gradual. "Crowned" points, if not too far gone, may be cleaned and returned to service. If excessive crowning has taken place, the points must be removed and replaced with a new or reconditioned set.

Item E of figure 4–64 illustrates a "built-up point that can be recognized by the mound of metal which has been transferred from one point to another. "Buildup," like the other conditions mentioned, results primarily from the transfer of contact material by means of the arc as the points separate. But, unlike the others, there is no burning or oxidation in the process because of the closeness of the pit of one point and the buildup of the other. This condition may result from excessive breaker point spring tension, which retards the opening of the points or causes a slow, lazy break. It can also be caused by a poor primary condenser or a loose connection at the primary coil. If excessive buildup has occurred, a new or reconditioned breaker assembly must be installed.

Item F of figure 4–64 illustrates "oily points," which can be recognized by their smoked and smudged appearance and by the lack of any of the above-mentioned irregularities. This condition may be the result of excessive cam lubrication or of oil vapors which may come from within or outside the magneto. A smoking or fuming engine, for example, could produce the oil vapors. These vapors then enter the magneto through the magneto ventilator and pass between and around the points. These conductive vapors produce arcing and burning on the contact surfaces. The vapors also adhere to the other surfaces of the breaker assembly and form the sooty deposit. Oily points can ordinarily be made serviceable by using a suitable cleaning procedure. However, the removal of smoke and smudge may reveal a need for dressing the points. If so, dress the points or install a new or reconditioned breaker assembly.

Dressing Breaker Points

Generally speaking, disassembly and dressing of breaker points should not be a regular routine step of magneto maintenance. By performing expensive and unnecessary maintenance on the point assemblies, many sets of points reach the scrap bin prematurely, with perhaps two-thirds to three-fourths of the platinum contact surface material filed away by repeated dressing operations. In a majority of the cases, breaker points will remain in satisfactory condition between overhaul periods with only routine inspection, cleaning, and lubrication.

If the breaker contacts have deep pits, mounds, or burnt surfaces, they should be dressed or replaced according to the maintenance practice recommended by the manufacturer. If dressing of breaker contacts is approved, a special contact point dressing kit will normally be available. The kit includes a contact point dressing block and adapters to hold the contacts during the dressing operation, a special file to remove the peaks and mounds, and a very fine whetstone to be used in the final dressing operation to remove any ridges or burrs left by the file.

While dressing a set of contacts that have pits and peaks, do not try to remove the pit completely. File only enough material to smooth and flatten the surface around the pit. This will usually leave plenty of contact area around the hole (figure 4–65) and the assembly will perform in the same manner as a new set of points. It is obvious that if the pit were deep, most of the platinum pad might be removed if an attempt were made to entirely eliminate the pit by filing.

In dressing off the peaked side of the set of contacts, the peak should be entirely filed off. The surface of this contact should be perfectly smooth and flat to provide the largest possible contact area against the other contact, which now will have a slightly decreased area due to the remaining pit. In completing the dressing operation, it is not necessary to obtain a mirror finish on the contact area; only a few strokes of the stone (figure 4–66) will

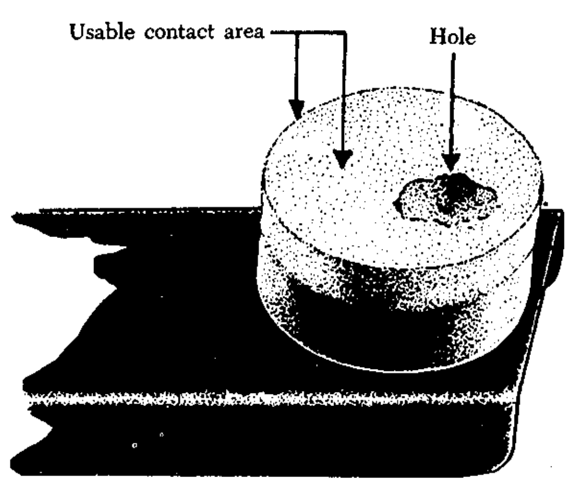


FIGURE 4–65. Pitted point after dressing.

be required to remove any ridges left by the file.

The primary objective is to have the contact surfaces flat so that they will provide a satisfactory contact area when assembled. A full contact area for the two reconditioned surfaces is often difficult to obtain, since it requires perfect flatness of the surfaces. This difficulty is somewhat compromised by an approach which permits about a two-thirds full contact area (figure 4–67), if the usable area is on the side away from the cam follower block. The actual contact surface can be checked by holding the assembled breaker in front of a light and observing whether light can be seen between the contact surfaces.

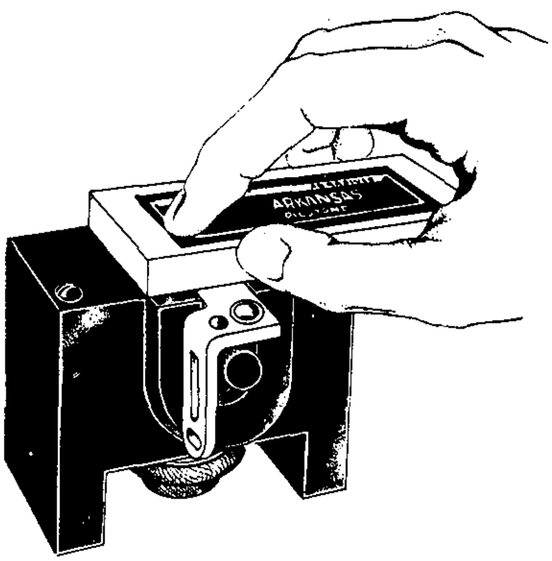


FIGURE 4–66. Using the contact point dressing stone.

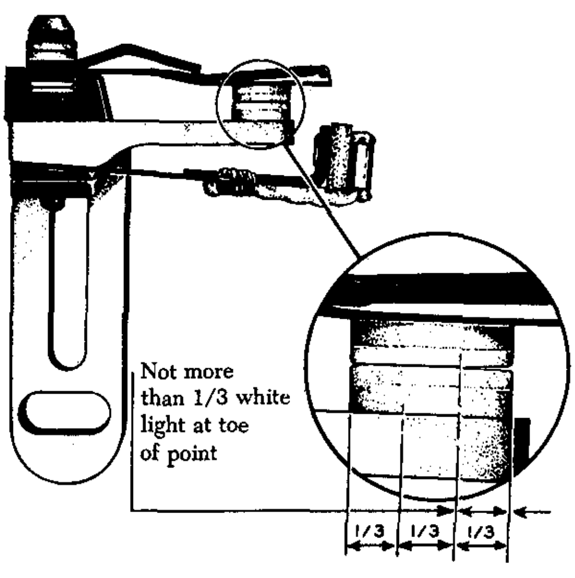


FIGURE 4–67. Checking breaker contact area.

If the breaker contact points have been removed for any reason, the replacement or reconditioned points must be installed and precisely timed to open just as the rotating magnet of the magneto moves into the E-gap position for the No. 1 cylinder.

Dielectric Inspection

Another phase of magneto inspection is the dielectric inspection. This inspection is a visual check for cleanliness and cracks. If inspection reveals that the coil cases, condensers, distributor rotor, or blocks are oily or dirty or have any trace of carbon tracking, they will require cleaning and possibly waxing to restore their dielectric qualities.

Clean all accessible condensers and coil cases which contain condensers by wiping them with a lint-free cloth moistened with acetone. Many parts of this type have a protective coating. This protective coating is not affected by acetone, but it may be damaged by scraping or by the use of other cleaning fluids. Never use unapproved cleaning solvents or improper cleaning methods. Also, when cleaning condensers or parts which contain condensers, do not dip, submerge, or saturate the parts in any solution because the solution used may seep inside the condenser and short out the plates.

Coil cases, distributor blocks, distributor rotors, and other dielectric parts of the ignition system are treated with a wax coating when they are new and again at overhaul. The waxing of dielectrics aids their resistance to moisture absorption, carbon tracking, and acid deposits. When these parts become dirty or oily, some of the original protection is lost, and carbon tracking may result.

If any hairline carbon tracks or acid deposits are present on the surface of the dielectric, immerse the part in approved cleaning solvent and scrub it vigorously with a stiff bristle brush. When the carbon track or acid deposits have been removed, wipe the part with a clean, dry cloth to remove all traces of the solvent used for cleaning. Then coat the part with a special ignition-treating wax. After wax treating the part, remove excess wax deposits and re-install the part in the magneto.

Ignition Harness Maintenance

Although the ignition harness is simple, it is a vital link between the magneto and spark plug. Because the harness is mounted on the engine and exposed to the atmosphere, it is vulnerable to heat, moisture, and the effects of changing altitude. These factors, plus aging insulation and normal gap erosion, work against efficient engine operation. The insulation may break down on a wire inside the harness and allow the high voltage to leak through the insulation to the harness shielding instead of going to the spark plug. Open circuits may result from broken wires or poor connections. A bare wire may be in physical contact with the shielding, or two wires may be shorted together.

Any serious defect in an individual lead prevents the high-tension impulse from reaching the spark plug to which the lead is connected. As a result this plug will not fire. When only one spark plug is firing in a cylinder, the charge is not consumed as quickly as it would be if both plugs were firing. This factor causes the peak pressure of combustion to occur later on the power stroke. If the peak pressure occurs later than normal, a loss of power in that cylinder results. However, the power loss from a single cylinder becomes a minor factor when the effect of a longer burning time is considered. A longer burning time overheats the affected cylinder, causing detonation, possible pre-ignition, and perhaps permanent damage to the cylinder.

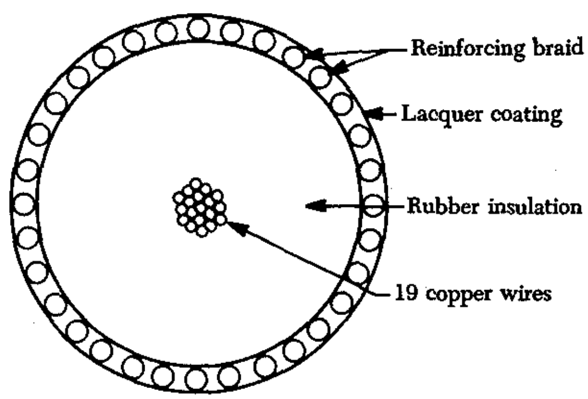
The insulated wire that carries the electrical impulse is a special type of cable designed to prevent excessive losses of electrical energy. This wire is known as high-tension ignition cable and is manufactured in three diameters. The outside diameters of cables in current use are 5, 7, or 9 mm. (millimeters). The reason for different cable diameters is that the amount and kind of insulation around the conducting core determines the amount of electrical loss during transmission of the high voltage. Since the conducting core carries only a weak current, the conductor is of a small diameter.

The 9-mm. cable has only a limited application now because it is of early design and has a relatively thick layer of insulation. For the most part, present-day engines use the 7-mm. size, but there are a few systems which are designed to use 5-mm. cable. The increased use of the smaller size cable is largely due to improvements in the insulation material, which permits a thinner insulating sheath. Adapter sleeves have been designed for the ends of the smaller improved cable so that it can be used in re-wirable harnesses where the distributor wells were originally designed for larger cable.

One type of cable construction uses a core consisting of 19 strands of fine copper wire covered with a rubber sheath. This, in turn, is covered by a reinforcing braid and an outside coat of lacquer (A of figure 4–68). A newer type of construction (B of figure 4–68) has a core of seven strands of stainless steel wire covered with a rubber sheath. Over this is woven a reinforcing braid, and a layer of neoprene is added to complete the assembly. This type of construction is superior to the older type primarily because the neoprene has improved resistance to heat, oil, and abrasion.

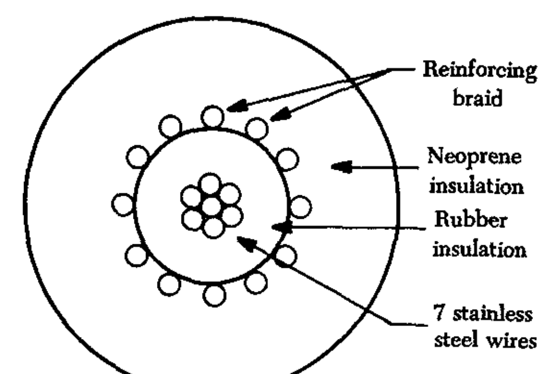
High-Tension Ignition Harness Faults

Perhaps the most common and most difficult high-tension ignition system faults to detect are high-voltage leaks. This is leakage from the core conductor through insulation to the ground of the shielded manifold. A certain small amount of leakage exists even in brand new ignition cable during normal operation. Various factors then combine to produce first a high rate of leakage and then complete breakdown. Of these factors, moisture in any form is probably the worst. Under high-voltage



A

A. Older types of construction



B

B. Newer types of construction

FIGURE 4–68. Cross-sectional view of typical high-tension ignition cable.

stress, an arc forms and burns a path across the insulator where the moisture exists. If there is gasoline or oil or grease present, it will break down and form carbon. The burned path is called a carbon track, since it is actually a path of carbon particles. With some types of insulation, it may be possible to remove the carbon track and restore the insulator to its former useful condition. This is generally true of porcelain, ceramics, and some of the plastics because these materials are not hydrocarbons, and any carbon track forming on them is the result of a dirt film that can be wiped away.

Differences in location and amount of leakage will produce different indications of malfunction during engine operation. Indications are generally misfiring or crossfiring. The indication may be intermittent, changing with manifold pressure or with climate conditions. An increase in manifold pressure increases the compression pressure and the resistance of the air across the airgap of the spark plugs. An increase in the resistance at the airgap opposes the spark discharge and produces a tendency for the spark to discharge at some weak point in the insulation. A weak spot in the harness may be aggravated by moisture collecting in the harness manifold. With moisture present, continued engine operation will cause the intermittent faults to become permanent carbon tracks. Thus, the first indication of ignition harness unserviceability may be engine misfiring or roughness caused by partial leakage of the ignition voltage.

Figure 4–69, showing a cross section of a harness, demonstrates four faults that may occur. Fault A shows a short from one cable conductor to another. This fault usually causes misfiring, since the spark is short circuited to a plug in a cylinder where the cylinder pressure is low. Fault B illustrates a cable with a portion of its insulation scuffed away. Although the insulation is not completely broken down, more than normal leakage exists, and the spark plug to which this cable is connected may be lost during takeoff when the manifold pressure is quite high.

Fault C is the result of condensation collecting in the lowest portion of the ignition manifold. This condensation may completely evaporate during engine operation, but the carbon track that is formed by the initial flashover remains to allow continued flashover whenever high manifold pressure exists. Fault D may be caused by a flaw in the insulation or the result of a weak spot in the insulation which is aggravated by the presence of moisture. However, since the carbon track is in direct contact with the metal shielding, it will probably result in flashover under all operating conditions.

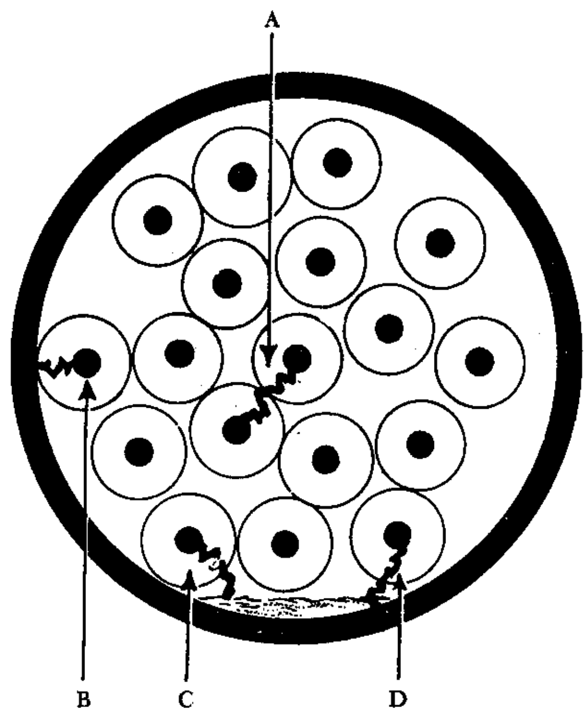


FIGURE 4–69. Cross section of an ignition harness.

Harness Testing

The electrical test of the ignition harness checks the condition or effectiveness of the insulation around each cable in the harness. The principle of this test involves application of a definite voltage to each lead and then measurement with a very sensitive meter of the amount of current leakage between the lead and the grounded harness manifold. This reading, when compared with known specifications, becomes a guide to the condition or serviceability of the cable. As mentioned earlier, there is a gradual deterioration of flexible insulating material. When new, the insulation will have a low rate of conductivity, so low, in fact, that under several thousand volts of electrical pressure the current leakage will be only a very few millionths of an ampere. Natural aging will cause an extremely slow, but certain, change in the resistance of insulating material, allowing an ever-increasing rate of current leakage.

Testing High-Tension Ignition Harness

Several different types of test devices are used for determining the serviceability of high-tension ignition harness. One common type of tester, illustrated in figure 4–70, is capable of applying a direct current in any desired voltage from zero to 15,000 volts with a 110-volt, 60-cycle input. The current leakage between ignition cable and ignition manifold is measured on two scales of a microammeter that is graduated to read from zero to 100 μa. (microampere) and from zero to 1,000 μa. Since 1,000 μa. are equal to 1 ma. (milliampere), the zero to 1,000 scale is called the ma. scale and the other a μa. scale. Readings may be obtained on either scale by the use of a high- or low-resistance range switch located on the right of the ammeter. Current-limiting resistors are used in both ranges to prevent damage to the test circuit through accidental application of excessive voltages.

The voltage impressed on the cable being tested is indicated on a voltmeter calibrated to read from zero to 15,000 volts. A control knob at the left of the voltmeter permits a voltage adjustment to the recommended test voltage. In addition to the ammeter and voltmeter, a neon light is provided to indicate flashover, which may be too rapid to cause noticeable needle deflection on the microammeter.

The control switches for the tester (figure 4–70) include a filament switch, plate switch, and remote switch. The filament switch completes a circuit

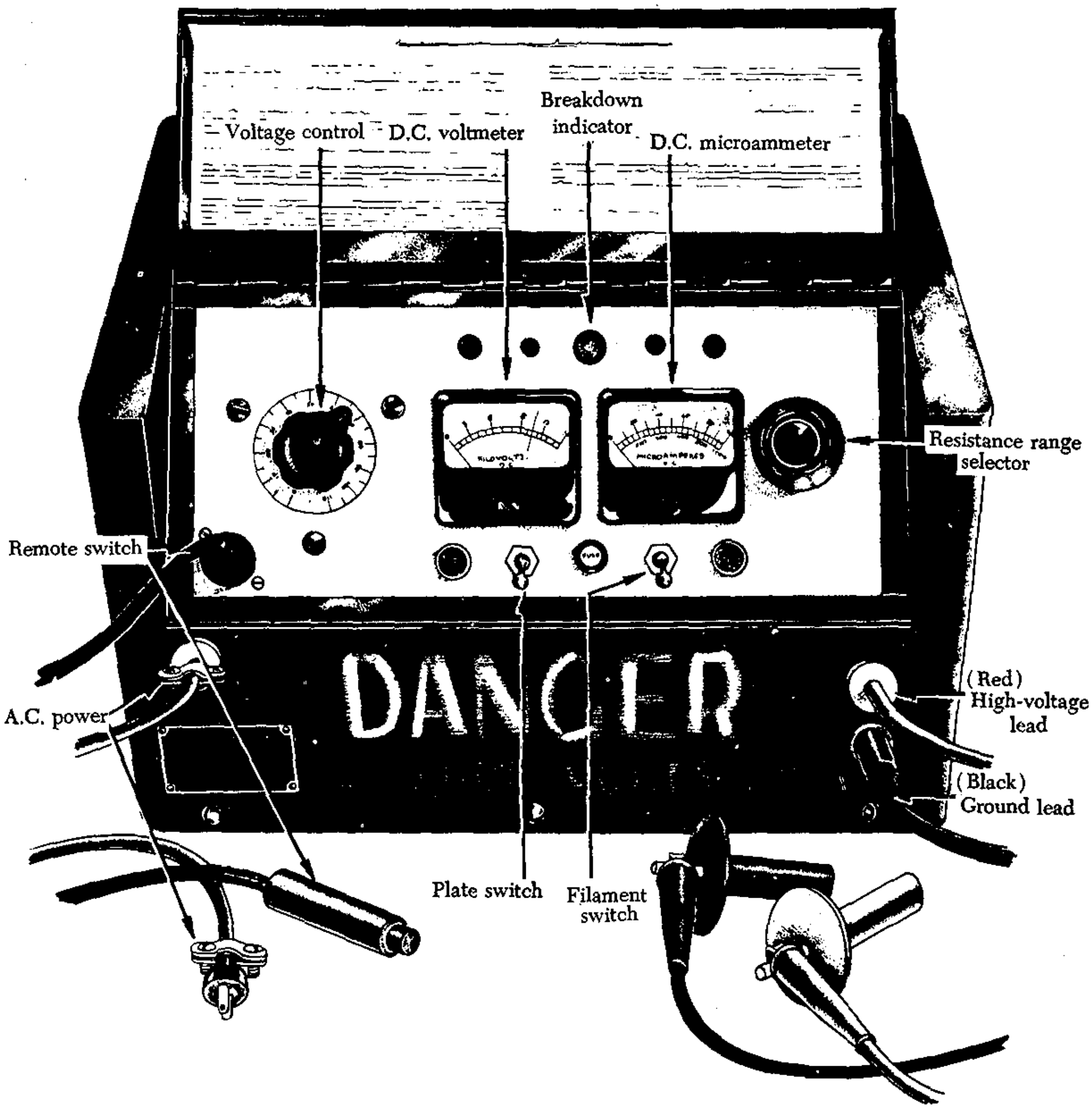


FIGURE 4–70. High-tension ignition harness tester.

between the a.c. input circuit and the filament element of the rectifier tube. Current flow to the filament heats the filament and prepares the tube for operation. The tube function, however, is not complete until the plate of the same tube is energized. The plate voltage of the rectifier is dependent on two switches, the plate control switch and the remote switch. The plate control switch arms or readies the plate circuit for operation. With the plate and filament switches on, depressing the remote switch will place the tube in operation and impress the test voltage to an ignition cable if the test leads are connected. The pushbutton remote switch must be plugged into a socket in the lower left-hand corner of the instrument panel. This switch arrangement permits operation of the tester at distances up to 5 ft.

The following paragraphs illustrate the use of this type of test unit. These instructions are presented as a general guide only. Consult the applicable manufacturer's instructions before performing an ignition harness test.

The ignition harness need not be removed from the engine to perform the harness test. If the test is performed with the harness on the engine, all spark plug leads must be disconnected from the plugs because the voltage applied during the test is high enough to cause an arc across the unpressurized airgap. After each lead is disconnected, each lead contact, except the lead to be tested, should be positioned against the cylinder so that it will be well grounded. The reason for grounding all spark plug leads during the test is to check and detect excessive leakage or breakdown resulting from short circuiting between two ignition leads. If the spark plug leads were ungrounded during the test, short circuiting could not be detected because all spark plug leads would have open circuits and only the insulation leakage to the ground potential of the harness manifold could be indicated. However, when all leads are grounded except the lead receiving the test voltage, a complete circuit is formed through short-circuited leads, and any leakage or excessive current flow to ground is indicated by the microammeter or the flashing of the neon light breakdown indicator.

When all the spark plug leads have been detached from the spark plugs and grounded to the engine, prepare the harness tester for the test. Begin by connecting the earth-ground binding post on the back of the tester to a rod driven into the earth or to a well-grounded object. Connect the red high-voltage lead (figure 4–70) to the high-voltage terminal on the tester. Connect the other end of the high-voltage test lead to the ignition harness lead being tested. Plug one end of the black ground lead into the ground receptacle on the front of the tester and the other end to the engine or some other common ground. Plug the remote switch lead into the ignition tester panel. Make sure all switches are turned off and the high-voltage control knob is set at zero; then connect the power supply lead to a 110-volt, 60-cycle a.c. power supply line. Turn the filament switch on and allow about 10 seconds for the filament in the tube to heat. After a 10-second interval, turn the plate switch on. With the plate and filament switches on, adjust the voltage that will be applied to each ignition cable during the test.

Adjustment is made by depressing the remote switch and rotating the high-voltage control knob clockwise until the voltmeter registers 10,000 volts. Just as soon as the recommended voltage is reached, release the remote switch. Releasing the remote switch automatically turns off the high-voltage supply. Once the voltage is adjusted to the recommended value, no further voltage adjustment is necessary throughout the test. The final step in setting up the tester is positioning the resistance range selector to the "high" position so that the current leakage can be easily read on the microammeter.

The test is usually started with the No. 1 cylinder. Since all spark plug leads are already grounded and the red high-voltage lead is connected to the No. 1 cylinder lead, test this lead by simply depressing the remote switch and observing the microammeter. When the test indication is known, release the remote switch, remove the high-voltage test lead, ground the ignition lead just tested, and proceed to the next lead in the cylinder numbering order. It is important that each lead, whether it tests good or bad, be re-grounded before conducting a further lead test. As the testing progresses around the engine, note only those leads by number which give an indication of excessive leakage (more than 50 μa.) or of breakdown indicated by flashing breakdown indicator.

At the completion of the test, at least two leads in any harness will probably show faults. This can be explained by referring to figure 4–71 and noting the position of the distributor rotor. When the test voltage is applied to the bottom lead of the illustration, a flashover may occur across the small distributor airgap and through the magneto primary coil to ground or through the ignition switch to ground. With synchronized firing, this apparent fault will

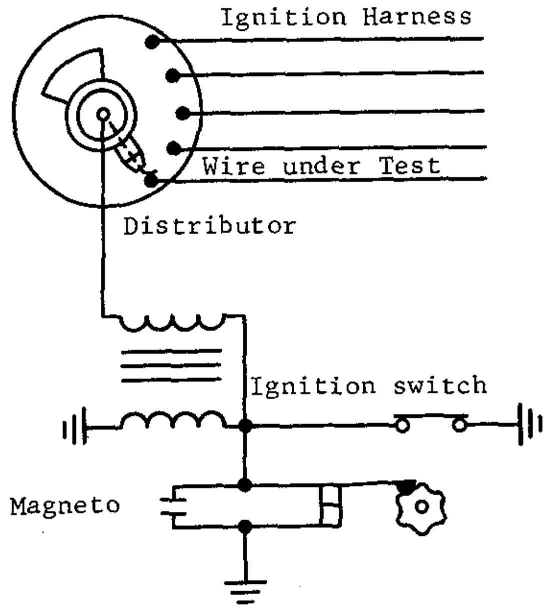


FIGURE 4–71. Breakdown not attributed to insulation failure.

show up in both front and rear spark plug leads for a particular cylinder. To determine whether or not a real breakdown exists in these cables, turn the propeller about one-fourth to one-half revolution and repeat the test on these leads. This will move the distributor rotor away from the lead terminal being tested and give an accurate indication of lead condition. Do not turn the propeller immediately after an apparently bad lead is located, since the distributor rotor may stop opposite another lead which has not been tested, making it necessary to turn the propeller again.

Anytime a majority of the leads show excessive leakage, the fault may be dirty or improperly treated distributor blocks. If this is the case, clean or wax the distributor block according to the procedures outlined in the applicable manufacturer's instructions.

D.C. Insulation Tester

There are several types of small, lightweight, portable testers that can operate from a regular 115-volt, 60-cycle a.c. power input or from an aircraft's 28-volt d.c. power supply.

These testers use essentially the same meters and switches as the high-tension ignition harness tester already discussed. Further, the indications of leakage and breakdown are practically the same. This type of tester is a portable instrument and can be hand-carried to any location.

THE ENGINE ANALYZER

The engine analyzer is an adaptation of the laboratory oscilloscope. It is a portable or permanently installed instrument, whose function is to detect, locate, and identify engine operating abnormalities such as those caused by a faulty ignition system, detonation, sticking valves, poor fuel injection, or the like. The need for a more positive means of detecting and locating operational troubles became evident with the introduction of the larger, more complex aircraft engines.

The majority of aircraft operational troubles are due to a faulty ignition system and are the type which usually show up at low altitude or during ground operation. However, many engine difficulties, especially those of the ignition system, occur during flight at high altitudes. Since high-altitude conditions cannot be simulated on the ground, it is desirable to have a unit which can, at all times, indicate engine operation abnormalities.

Engine analyzers are generally classified into two types. One type produces evidence of the condition of the ignition system only. The other type reveals abnormal vibrations during operation such as those caused by detonation, valve sticking, and poor fuel distribution, as well as ignition malfunctions.

Analyzers are designed to be used as portable analyzers or as permanently installed equipment in an aircraft. Most standard models contain the ignition voltage control feature and selector switches, which permit the use of either the induction pickup, the breaker assembly, or the three-phase generator for synchronization.

The weight of airborne and portable-airborne installations will vary with the particular installation involved. On a typical twin-engine transport aircraft equipped with low-tension ignition, the portable/airborne installation weighs about 22.0 lbs. (including wire, connectors, and equipment). The airborne installation weighs approximately 45.5 lbs.

An airborne installation is one in which the ignition analyzer unit and its associated equipment are permanently installed in the aircraft. No storage locker for the leads is used. A portable/airborne installation is one in which the associated equipment is permanently installed in the aircraft, but the analyzer is eliminated. A storage locker for the leads is used. In the latter instance, the analyzer is carried from aircraft to aircraft to make ignition checks, or it is flown with the aircraft for those ignition checks to be made at altitude.

The airborne analyzer installation has one major advantage: the analyzer is always with the aircraft. To make such an installation involves the added cost of the analyzer. Obviously, it demands that the aircraft have personnel on board able to operate the instrument in flight. It permits flight personnel to check the ignition system before landing and, thus, makes it possible to have the difficulties promptly attended to after landing.

The diagram in figure 4–72 illustrates an airborne ignition analyzer installation in a typical aircraft. It shows that one breaker and filter assembly is required per engine. Only one relay/resistor box is required per aircraft. An exception to this rule is those aircraft having certain types of high-tension ignition installations. These installations require one relay/resistor box per engine.

The synchronizing breaker assembly "triggers" the horizontal sweep circuit of the cathode-ray tube. It operates at one-half engine crankshaft speed and is timed 3° to 4° before the firing of the No. 1 cylinder.

The radio interference filter is mounted on the firewall and in the ignition primary circuit. The number of units per filter depends on the number of ground wires carried in each ignition primary circuit. A unit normally consists of a choke coil and one or two condensers wired in parallel with the magneto primary condenser. The filter is required because the associated analyzer equipment is not radio shielded. It also permits the analyzer primary circuit wiring to be unshielded.

The relay/resistor box contains an isolating resistor for each engine. It also contains hermetically sealed relays, which will permit the selective and individual bypassing of the resistors for any engine. The isolating resistors are to prevent any short-to-ground in the analyzer circuit from grounding an engine magneto. The bypass relays permit the ignition voltage control to be used.

The panel assembly contains an engine and condition selector switch, individual relay operation toggle switches for each engine (guards are installed to prevent accidental operation of the switch), and a power switch complete with fuse and pilot light. It is the control center for the analyzer.

A block diagram of an ignition analyzer is shown

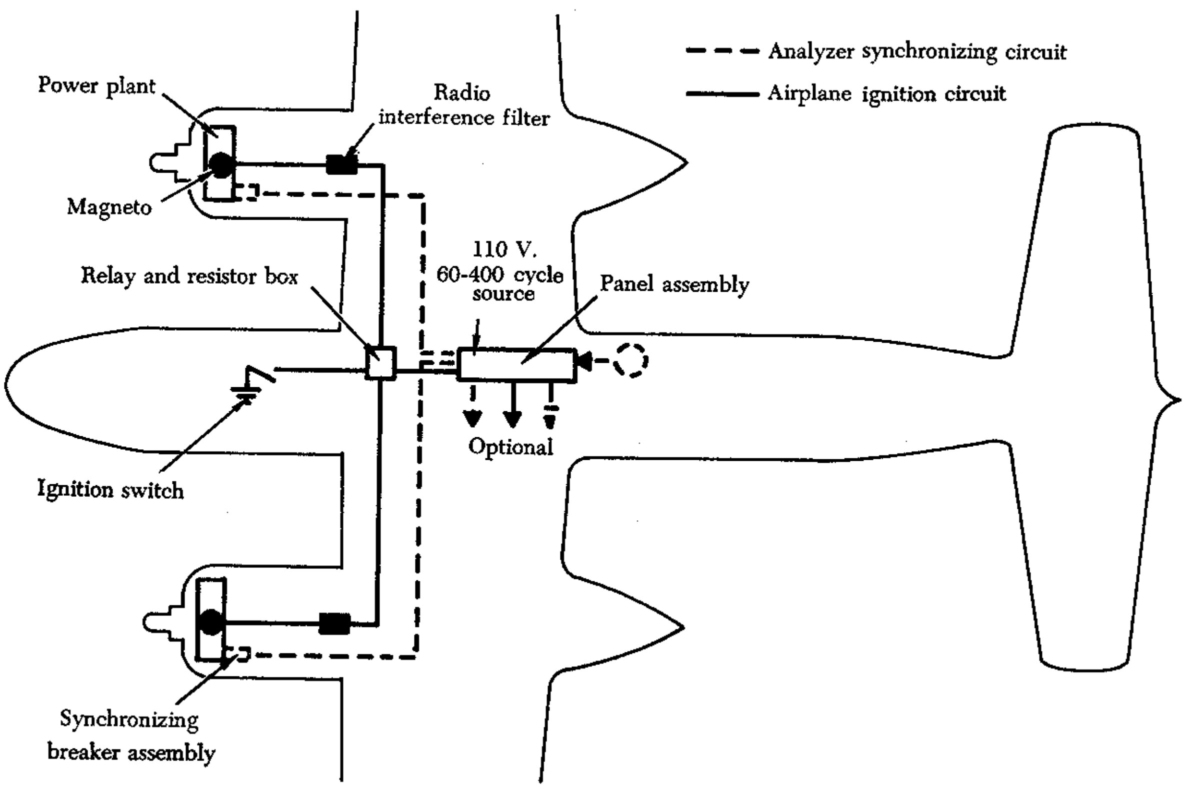


FIGURE 4–72. Twin-engine analyzer installation.

in figure 4–73. Signals can be traced from any of the three possible types of signal pickup devices to the display on the face of the cathode-ray tube.

Figure 4–74 illustrates six typical engine analyzer patterns. Although additional training is required before one can accurately interpret the meaning of each signal, the configuration of the signals in figure 4–74 shows that every malfunction presents a distinctive and recognizable picture.

TURBINE ENGINE IGNITION SYSTEMS

Since turbine ignition systems are operated for a brief period during the engine-starting cycle, they are, as a rule, more trouble-free than the typical reciprocating engine ignition system. Most turbojet engines are equipped with a high-energy, capacitor-type ignition system. Both turbojet and turboprop engines may be equipped with an electronic-type ignition system, which is a variation of the simpler capacitor-type system.

Turbojet Engine Ignition System

The typical turbojet engine is equipped with a capacitor-type (capacitor discharge) ignition system consisting of two identical independent ignition units operating from a common low-voltage d.c. electrical power source, the aircraft battery. Turbojet engines can be ignited readily in ideal atmospheric conditions, but since they often operate in the low temperatures of high altitudes, it is imperative that the system be capable of supplying a high-heat-intensity spark. Thus, a high voltage is supplied to arc across a wide igniter spark gap, providing the ignition system with a high degree of reliability under widely varying conditions of altitude, atmospheric pressure, temperature, fuel vaporization, and input voltage.

A typical ignition system includes two exciter units, two transformers, two intermediate ignition leads, and two high-tension leads. Thus, as a safety factor, the ignition system is actually a dual system, designed to fire two igniter plugs. Figure 4–75 shows one side of a typical ignition system.

Figure 4–76 is a functional schematic diagram of a typical capacitor-type turbojet ignition system. A 24-volt d.c. input voltage is supplied to the input receptacle of the exciter unit.

Before the electrical energy reaches the exciter

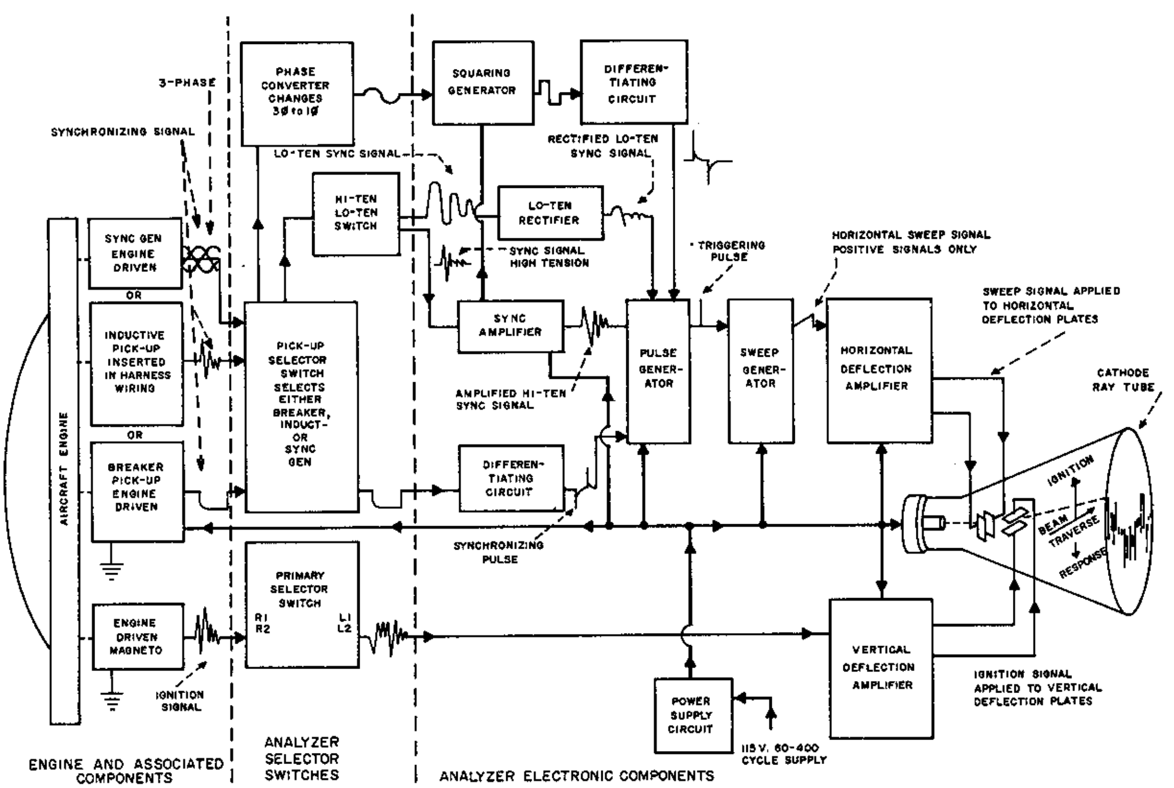


FIGURE 4–73. Diagram of ignition analyzer.

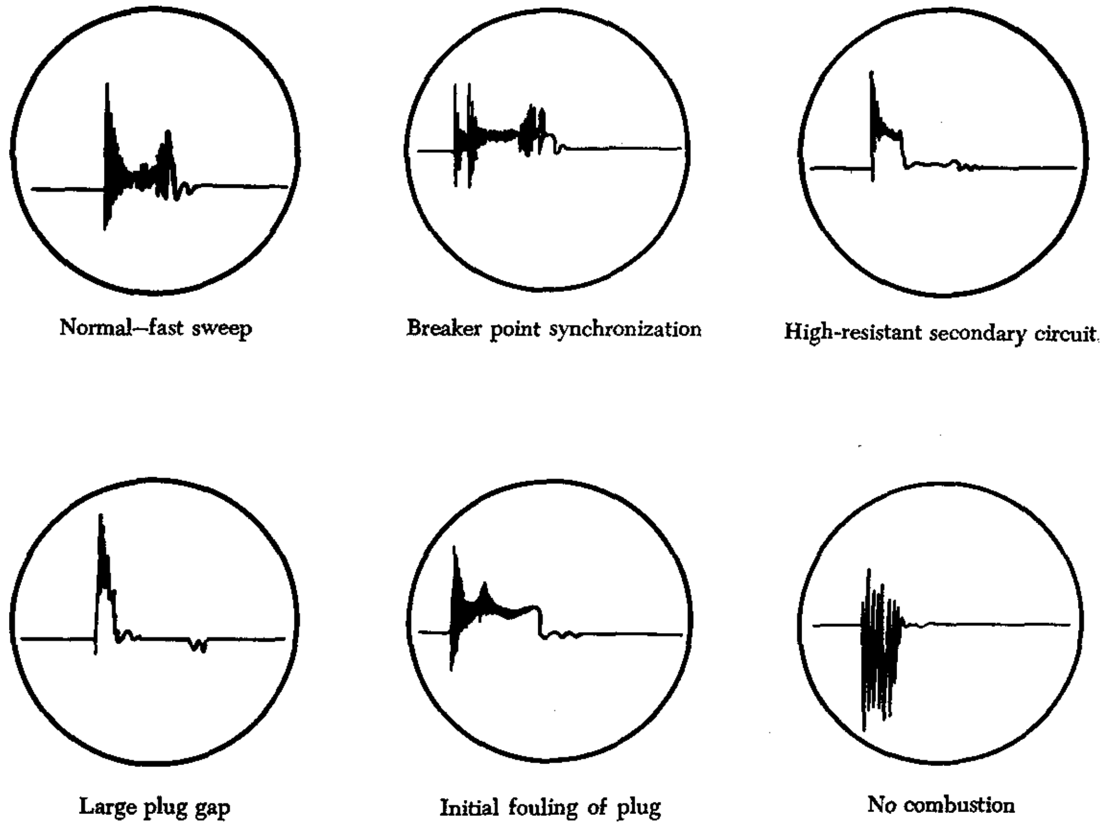


FIGURE 4–74. Typical engine analyzer patterns.

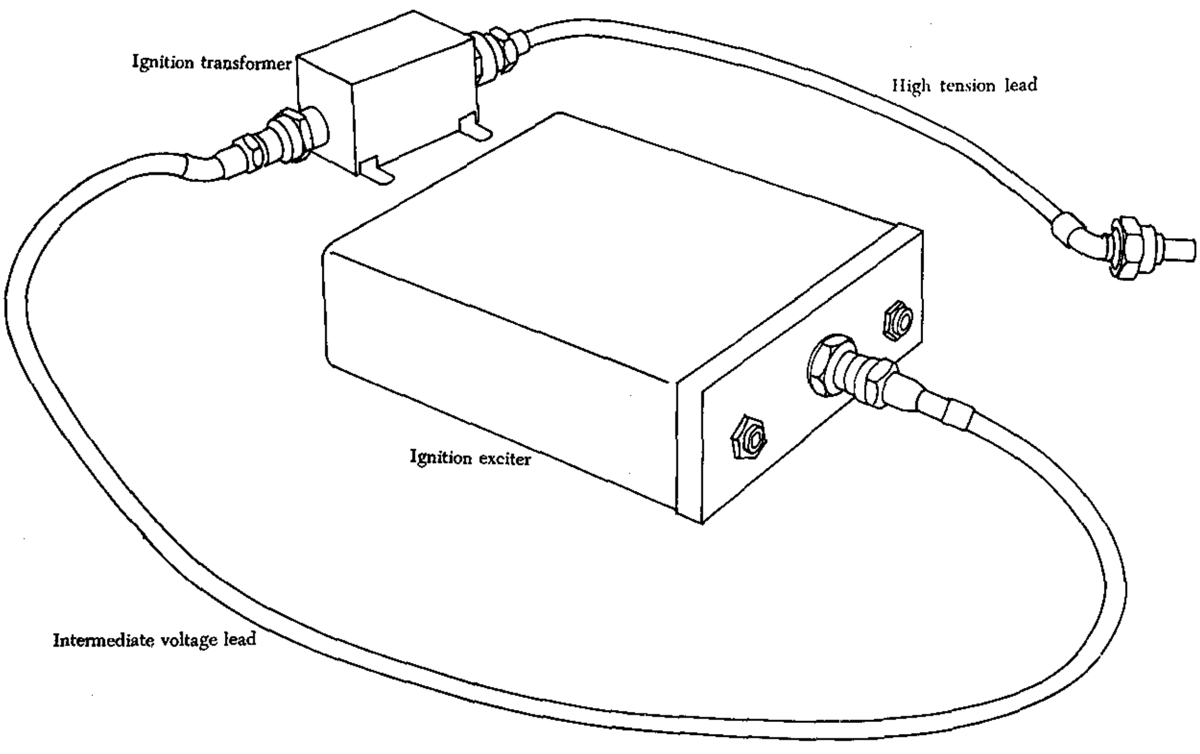


FIGURE 4–75. One side of a typical ignition system.

unit, it passes through a filter which prevents noise voltage from being induced into the aircraft electrical system. The low-voltage input power operates a d.c. motor, which drives one multi-lobe cam and one single-lobe cam. At the same time, input power is supplied to a set of breaker points that are actuated by the multi-lobe cam.

From the breaker points, a rapidly interrupted current is delivered to an auto transformer. When the breaker closes, the flow of current through the primary winding of the transformer establishes a magnetic field. When the breaker opens, the flow of current stops, and the collapse of the field induces a voltage in the secondary of the transformer. This voltage causes a pulse of current to flow into the storage capacitor through the rectifier, which limits the flow to a single direction. With repeated pulses the storage capacitor thus assumes a charge, up to a maximum of approximately 4 joules. (One joule per second equals 1 watt.)

The storage capacitor is connected to the spark igniter through the triggering transformer and a contactor, normally open. When the charge on the capacitor has built up, the contactor is closed by the mechanical action of the single-lobe cam. A portion of the charge flows through the primary of the triggering transformer and the capacitor connected in series with it.

This current induces a high voltage in the secondary which ionizes the gap at the spark igniter.

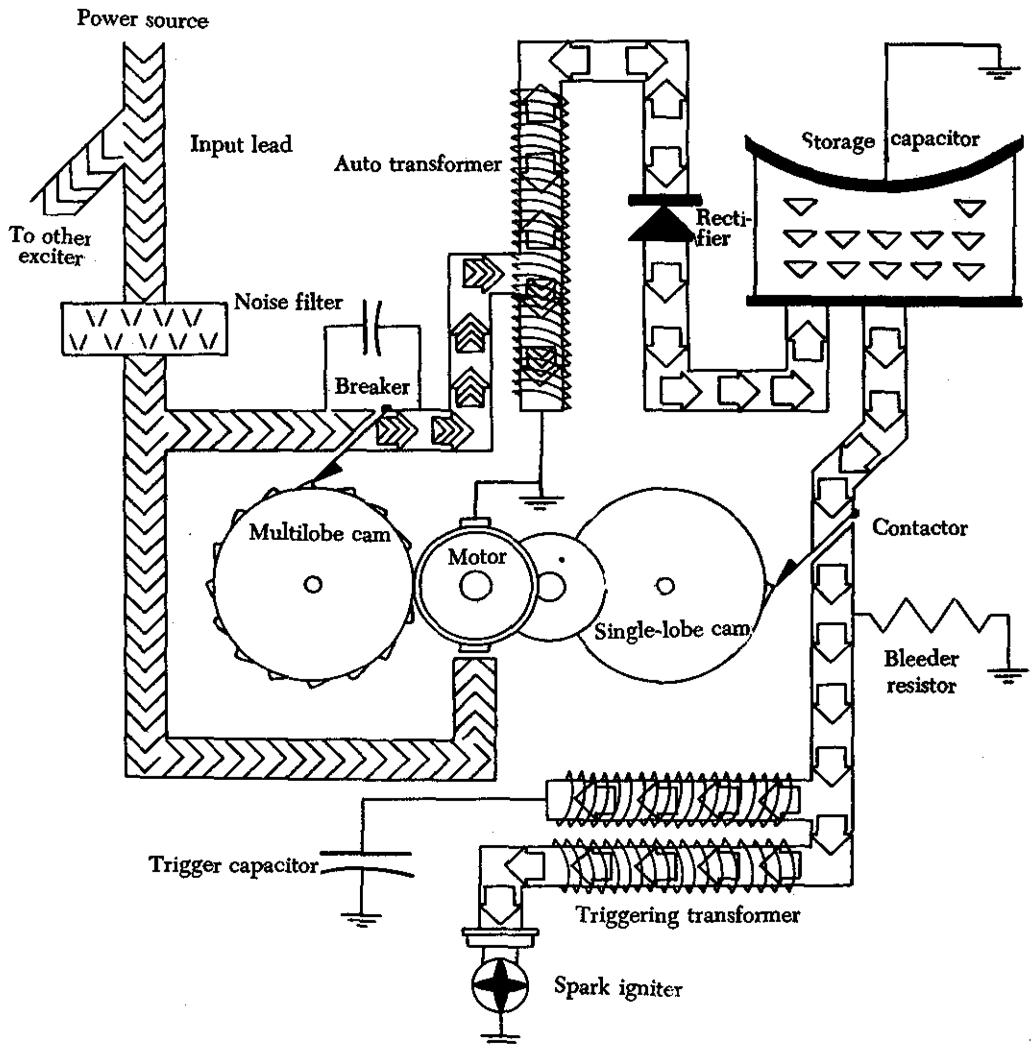


FIGURE 4–76. Capacitor-type ignition system schematic.

When the spark igniter is made conductive, the storage capacitor discharges the remainder of its accumulated energy together with the charge from the capacitor in series with the primary of the triggering transformer.

The spark rate at the spark igniter will vary in proportion to the voltage of the d.c. power supply which affects the r.p.m. of the motor. However, since both cams are geared to the same shaft, the storage capacitor will always accumulate its store of energy from the same number of pulses before discharge.

The employment of the high-frequency triggering transformer, with a low reactance secondary winding, holds the time duration of the discharge to a minimum. This concentration of maximum energy in minimum time achieves an optimum spark for ignition purposes, capable of blasting carbon deposits and vaporizing globules of fuel.

All high voltage in the triggering circuits is completely isolated from the primary circuits. The complete exciter is hermetically sealed, protecting all components from adverse operating conditions, eliminating the possibility of flashover at altitude due to pressure change. This also ensures shielding against leakage of high-frequency voltage interfering with the radio reception of the aircraft.

Electronic Ignition System

This modified capacity-type system provides ignition for turbojet and turboprop engines. Like other turbine ignition systems, it is required only for starting the engine; once combustion has begun, the flame is continuous. Figure 4–77 shows the components of a typical electronic ignition system.

The system consists of a dynamotor/regulator/filter assembly, an exciter unit, two high-tension transformer units, two high-tension leads, and two igniter plugs. Used with these components are the necessary interconnecting cables, leads, control switches, and associated equipment for operation in an aircraft.

The dynamotor is used to step up the direct current of the aircraft battery or the external power supply to the operating voltage of the exciter unit. This voltage is used to charge two storage capacitors which store the energy to be used for ignition purposes.

In this system, the energy required to fire the igniter plug in the engine burner is not stored in an inductor coil as in conventional types of igniters.

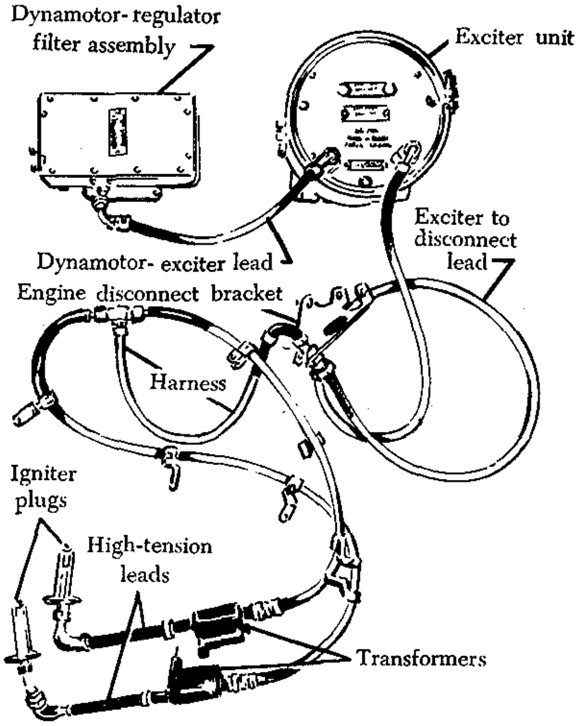


FIGURE 4–77. Typical electronic ignition system.

Instead, the energy is stored in capacitors. Each discharge circuit incorporates two storage capacitors. Both are located in the exciter unit. The voltage across these capacitors is stepped up by transformer units. At the instant of igniter plug firing, the resistance of the gap is lowered sufficiently to permit the larger capacitor to discharge across the gap. The discharge of the second capacitor is of low voltage but of very high energy. The result is a spark of great heat intensity, capable not only of igniting abnormal fuel mixtures but also of burning away any foreign deposits on the plug electrodes.

The exciter is a dual unit, and it produces sparks at each of the two igniter plugs. A continuous series of sparks is produced until the engine starts. The battery current is then cut off, and the plugs do not fire while the engine is operating.

Igniter Plugs

The igniter plug of a turbine engine ignition system differs considerably from the spark plug of a reciprocating engine ignition system. Its electrode must be capable of withstanding a current of much higher energy than the electrode of a conventional spark plug. This high-energy current can quickly cause electrode erosion, but the short periods of operation minimize this aspect of igniter maintenance. The electrode gap of the typical igniter plug is designed much larger than that of a spark plug, since the operating pressures are much lower and the spark can arc more easily than is the case for a spark plug. Finally, electrode fouling, so common to the spark plug, is minimized by the heat of the high-intensity spark.

Figure 4–78 is a cutaway illustration of a typical annular-gap igniter plug, sometimes referred to as a "long reach" igniter because it projects slightly into the combustion-chamber liner to produce a more effective spark.

Another type of igniter plug, the constrained-gap plug (figure 4–79) is used in some types of turbine engines. It operates at a much cooler temperature because it does not project into the combustion-chamber liner. This is possible because the spark does not remain close to the plug, but arcs beyond the face of the combustion-chamber liner.

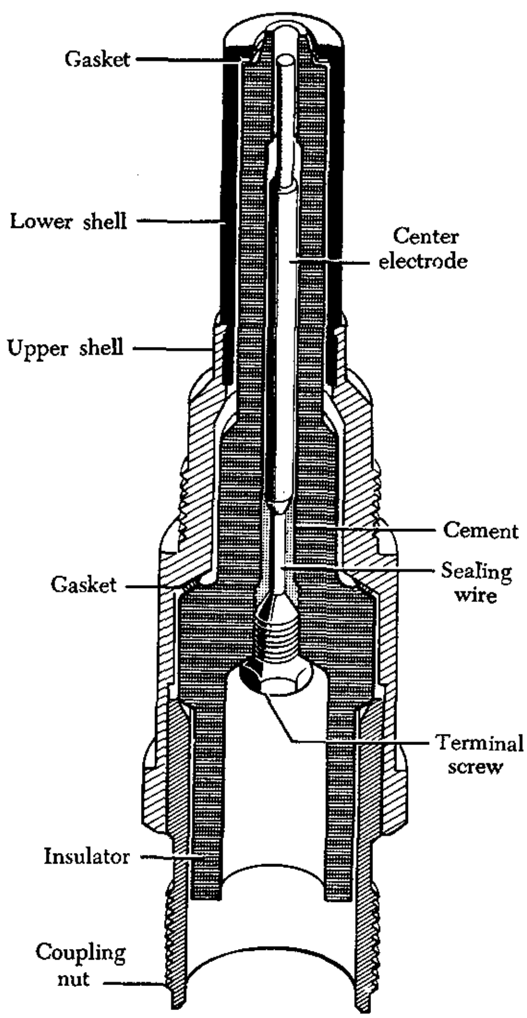


FIGURE 4–78. Typical annular-gap igniter plug.

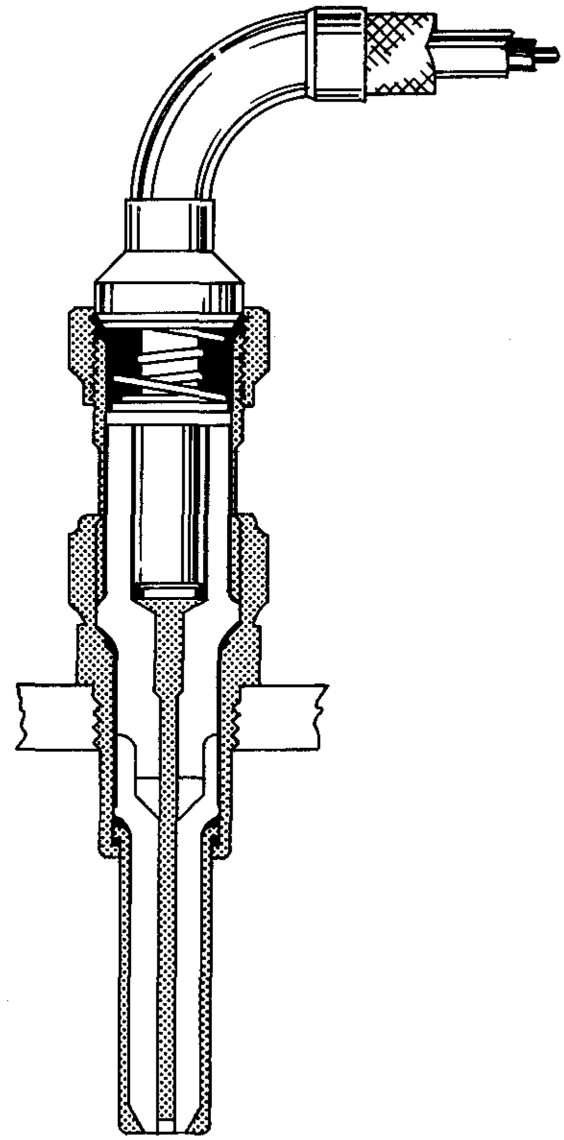


FIGURE 4–79. Constrained-gap igniter plug.

IGNITION SYSTEM INSPECTION AND MAINTENANCE

Maintenance of the typical turbine engine ignition system consists primarily of inspection, test, troubleshooting, removal, and installation.

Inspection

Inspection of the ignition system normally includes the following:

Inspection/Check	***Repair***
Security of components, bolts, and brackets.	Tighten and secure as required.
Shorts or high-voltage arcing.	Replace faulty components and wiring.
Loose connections.	Secure, tighten, and safety as required.

REMOVAL, MAINTENANCE, AND INSTALLATION OF IGNITION SYSTEM COMPONENTS

The following instructions are typical procedures suggested by many gas turbine manufacturers. These instructions are applicable to the engine ignition components illustrated in figure 4–77. Always consult the applicable manufacturer's instructions before performing any ignition system maintenance.

Ignition System Leads

(1) Remove clamps securing ignition leads to engine.
(2) Remove safety wire and disconnect electrical connectors from exciter units.
(3) Remove safety wire and disconnect lead from igniter plug.
(4) Discharge any electrical charge stored in the system by grounding, and remove ignition leads from engine.
(5) Clean leads with approved drycleaning solvent.
(6) Inspect connectors for damaged threads, corrosion, cracked insulators, and bent or broken connector pins.
(7) Inspect leads for worn or burned areas, deep cuts, fraying, and general deterioration.
(8) Perform continuity check of ignition leads.
(9) Re-install leads, reversing the removal procedure.

Igniter Plugs

(1) Disconnect ignition leads from igniter plugs.
(2) Remove igniter plugs from mounts.
(3) Inspect igniter plug gap surface material.
(4) Inspect for fretting of igniter plug shank.
(5) Replace an igniter plug whose surface is granular, chipped, or otherwise damaged.
(6) Replace dirty or carbonized igniter plugs.
(7) Install igniter plugs in mounting pads.
(8) Check for proper clearance between chamber liner and igniter plug.
(9) Tighten igniter plugs to manufacturer's specified torque.
(10) Safety-wire igniter plugs.

POWERPLANT ELECTRICAL SYSTEMS

The satisfactory performance of any modern aircraft depends to a very great degree on the continuing reliability of electrical systems and subsystems. Improperly or carelessly installed or maintained wiring can be a source of both immediate and potential danger. The continued proper performance of electrical systems depends upon the knowledge and technique of the mechanic who installs, inspects, and maintains the electrical wire and cable of the electrical systems.

The procedures and practices outlined in this section are general recommendations and are not intended to replace the manufacturer's instructions in approved practices.

For the purpose of this discussion, a wire is described as a single solid conductor, or a stranded conductor covered with an insulating material. Figure 4–80 illustrates these two definitions of a wire.

The term cable as used in aircraft electrical installations includes the following:

(1) Two or more separately insulated conductors in the same jacket (multi-conductor cable).
(2) Two or more separately insulated conductors twisted together (twisted pair).
(3) One or more insulated conductors, covered with a metallic braided shield (shielded cable).
(4) A single insulated center conductor with a metallic braided outer conductor (radio frequency cable). The concentricity of the center conductor and the outer conductor is carefully controlled during manufacture to ensure that they are coaxial.

Wire Size

Wire is manufactured in sizes according to a standard known as the AWG (American wire gage). As shown in the chart in figure 4–81, the wire diameters become smaller as the gage numbers become larger. The largest wire size shown in figure 4–81 is number 0000, and the smallest is

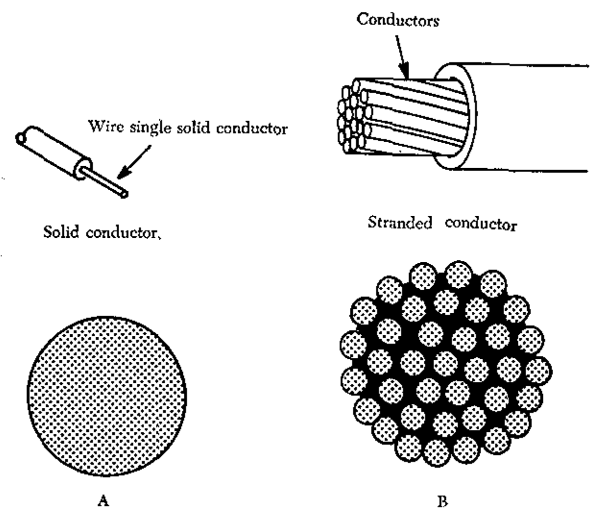


FIGURE 4–80. Two types of aircraft wire.

Gage number	Diameter (mils)	Cross section: Circular mils	Cross section: Square inches	Ohms per 1,000 ft.: 25°C. (=77°F.)	Ohms per 1,000 ft.: 65°C. (=149°F.)
0000	460.0	212,000.0	0.166	0.0500	0.0577
000	410.0	168,000.0	.132	.0630	.0727
00	365.0	133,000.0	.105	.0795	.0917
0	325.0	106,000.0	.0829	.100	.116
1	289.0	83,700.0	.0657	.126	.146
2	258.0	66,400.0	.0521	.159	.184
3	229.0	52,600.0	.0413	.201	.232
4	204.0	41,700.0	.0328	.253	.292
5	182.0	33,100.0	.0260	.319	.369
6	162.0	26,300.0	.0206	.403	.465
7	144.0	20,800.0	.0164	.508	.586
8	128.0	16,500.0	.0130	.641	.739
9	114.0	13,100.0	.0103	.808	.932
10	102.0	10,400.0	.00815	1.02	1.18
11	91.0	8,230.0	.00647	1.28	1.48
12	81.0	6,530.0	.00513	1.62	1.87
13	72.0	5,180.0	.00407	2.04	2.36
14	64.0	4,110.0	.00323	2.58	2.97
15	57.0	3,260.0	.00256	3.25	3.75
16	51.0	2,580.0	.00203	4.09	4.73
17	45.0	2,050.0	.00161	5.16	5.96
18	40.0	1,620.0	.00128	6.51	7.51
19	36.0	1,290.0	.00101	8.21	9.48
20	32.0	1,020.0	.000802	10.4	11.9
21	28.5	810.0	.000636	13.1	15.1
22	25.3	642.0	.000505	16.5	19.0
23	22.6	509.0	.000400	20.8	24.0
24	20.1	404.0	.000317	26.2	30.2
25	17.9	320.0	.000252	33.0	38.1
26	15.9	254.0	.000200	41.6	48.0
27	14.2	202.0	.000158	52.5	60.6
28	12.6	160.0	.000126	66.2	76.4
29	11.3	127.0	.0000995	83.4	96.3
30	10.0	101.0	.0000789	105.0	121.0
31	8.9	79.7	.0000626	133.0	153.0
32	8.0	63.2	.0000496	167.0	193.0
33	7.1	50.1	.0000394	211.0	243.0
34	6.3	39.8	.0000312	266.0	307.0
35	5.6	31.5	.0000248	335.0	387.0
36	5.0	25.0	.0000196	423.0	488.0
37	4.5	19.8	.0000156	533.0	616.0
38	4.0	15.7	.0000123	673.0	776.0
39	3.5	12.5	.0000098	848.0	979.0
40	3.1	9.9	.0000078	1,070.0	1,230.0

FIGURE 4–81. American wire gage for standard annealed solid copper wire.

number 40. Larger and smaller sizes are manufactured but are not commonly used.

Wire size may be determined by using a wire gage (figure 4–82). This type of gage will measure wires ranging in size from number zero to number 36. The wire to be measured is inserted in the smallest slot that will just accommodate the bare wire. The gage number corresponding to that slot indicates the wire size. The slot has parallel sides and should not be confused with the semicircular opening at the end of the slot. The opening simply permits the free movement of the wire all the way through the slot.

Gage numbers are useful in comparing the diameter of wires, but not all types of wire or cable can be accurately measured with a gage. Large wires are usually stranded to increase their flexibility. In such cases, the total area can be determined by multiplying the area of one strand (usually computed in circular mils when diameter or gage number is known) by the number of strands in the wire or cable.

Factors Affecting the Selection of Wire Size

Several factors must be considered in selecting the size of wire for transmitting and distributing electric power.

One factor is the allowable power loss (I^2R loss) in the line. This loss represents electrical energy converted into heat. The use of large conductors will reduce the resistance and therefore the I^2R loss. However, large conductors are more expensive initially than small ones; they are heavier and require more substantial supports.

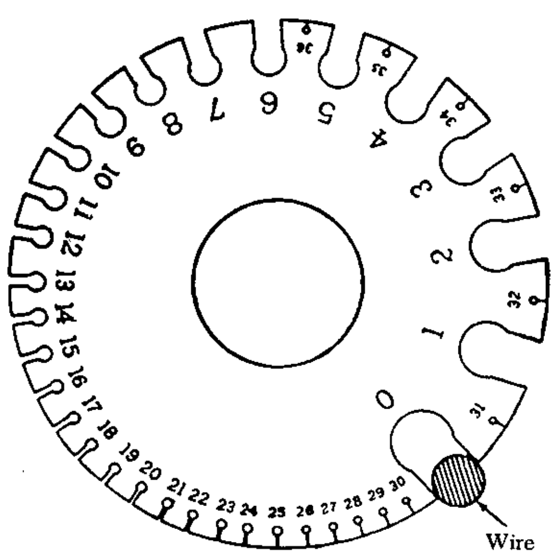


FIGURE 4–82. A wire gage.

A second factor is the permissible voltage drop (IR drop) in the line. If the source maintains a constant voltage at the input to the line, any variation in the load on the line will cause a variation in line current and a consequent variation in the IR drop in the line. A wide variation in the IR drop in the line causes poor voltage regulation at the load. The obvious remedy is to reduce either current or resistance. A reduction in load current lowers the amount of power being transmitted, whereas a reduction in line resistance increases the size and weight of conductors required. A compromise is generally reached whereby the voltage variation at the load is within tolerable limits and the weight of line conductors is not excessive.

A third factor is the current-carrying ability of the conductor. When current is drawn through the conductor, heat is generated. The temperature of the wire will rise until the heat radiated, or otherwise dissipated, is equal to the heat generated by the passage of current through the line. If the conductor is insulated, the heat generated in the conductor is not so readily removed as it would be if the conductor were not insulated. Thus, to protect the insulation from too much heat, the current through the conductor must be maintained below a certain value.

When electrical conductors are installed in locations where the ambient temperature is relatively high, the heat generated by external sources constitutes an appreciable part of the total conductor heating. Allowance must be made for the influence of external heating on the allowable conductor current, and each case has its own specific limitations. The maximum allowable operating temperature of insulated conductors varies with the type of conductor insulation being used.

Tables are available that list the safe current ratings for various sizes and types of conductors covered with various types of insulation. The chart in figure 4–83 shows the current-carrying capacity, in amperes, of single copper conductors at an ambient temperature of below 30° C. This example provides measurements for only a limited range of wire sizes.

Factors Affecting Selection of Conductor Material

Although silver is the best conductor, its cost limits its use to special circuits where a substance with high conductivity is needed.

The two most generally used conductors are copper and aluminum. Each has characteristics

Size	Rubber or thermo-plastic	Thermoplastic asbestos, var-cam, or asbestos var-cam	Impregnated asbestos	Asbestos	Slow-burning or weather-proof
0000	300	385	475	510	370
000	260	330	410	430	320
00	225	285	355	370	275
0	195	245	305	325	235
1	165	210	265	280	205
2	140	180	225	240	175
3	120	155	195	210	150
4	105	135	170	180	130
6	80	100	125	135	100
8	55	70	90	100	70
10	40	55	70	75	55
12	25	40	50	55	40
14	20	30	40	45	30

FIGURE 4–83. Current-carrying capacity of wire (in amperes).

that make its use advantageous under certain circumstances; also, each has certain disadvantages.

Copper has a higher conductivity; it is more ductile (can be drawn out), has relatively high tensile strength, and can be easily soldered. It is more expensive and heavier than aluminum.

Although aluminum has only about 60% of the conductivity of copper, it is used extensively. Its lightness makes possible long spans, and its relatively large diameter for a given conductivity reduces corona, the discharge of electricity from the wire when it has a high potential. The discharge is greater when smaller diameter wire is used than when larger diameter wire is used. Some bus bars are made of aluminum instead of copper, where there is a greater radiating surface for the same conductance. The characteristics of copper and aluminum are compared in table 2.

TABLE 2. Characteristics of copper and aluminum.

Characteristic	*Copper*	*Aluminum*
Tensile strength (lb./in.^{2})	55,000	25,000
Tensile strength for same conductivity (lb.)	55,000	40,000
Weight for same conductivity (lb.)	100	48
Cross section for same conductivity (C.M.)	100	160
Specific resistance (Ω/mil ft.)	10.6	17

Voltage Drop in Aircraft Wire and Cable

It is recommended that the voltage drop in the main power cables from the aircraft generation source or the battery to the bus should not exceed 2% of the regulated voltage when the generator is carrying rated current or the battery is being discharged at a 5-minute rate. Table 3 shows the recommended maximum voltage drop in the load circuits between the bus and the utilization equipment.

TABLE 3. Recommended maximum voltage drop in load circuits.

Nominal system voltage	*Allowable voltage drop*	
	Continuous operation	*Intermittent operation*
14	0.5	1
28	1	2
115	4	8
200	7	14

The resistance of the current return path through the aircraft structure is always considered negligible. However, this is based on the assumption that adequate bonding of the structure or a special electric current return path has been provided which is capable of carrying the required electric current with a negligible voltage drop. A resistance measurement of 0.005 ohms from ground point of the generator or battery to ground terminal of any electrical device is considered satisfactory. Another satisfactory method of determining circuit resistance is to check the voltage drop across the circuit. If the voltage drop does not exceed the limit established by the aircraft or product manufacturer, the resistance value for the circuit is considered satisfactory. When using the voltage drop method of checking a circuit, the input voltage must be maintained at a constant value.

The chart in figure 4–84 applies to copper conductors carrying direct current. Curves 1, 2, and 3 are plotted to show the maximum ampere rating for the specified conductor under the specified conditions shown. To select the correct size of conductor, two major requirements must be met. First, the size must be sufficient to prevent an excessive voltage drop while carrying the required current over the required distance. Secondly, the size must be sufficient to prevent overheating of the cable while carrying the required current. The charts in figures 4–84 and 85 can simplify these determinations. To use this chart to select the proper size of conductor, the following must be known:

(1) The conductor length in feet.

(2) The number of amperes of current to be carried.

(3) The amount of voltage drop permitted.

(4) Whether the current to be carried will be intermittent or continuous, and if continuous, whether it is a single conductor in free air, in a conduit, or in a bundle.

Assume that it is desired to install a 50-foot conductor from the aircraft bus to the equipment in a 28-volt system. For this length, a 1-volt drop is permissible for continuous operation. By referring to the chart in figure 4–84 the maximum number of feet a conductor may be run carrying a specified current with a 1-volt drop can be determined. In this example the number 50 is selected.

Assuming the current required by the equipment is 20 amperes, the line indicating the value of 20 amperes should be selected from the diagonal lines. Follow this diagonal line downward until it intersects the horizontal line number 50. From this point, drop straight down to the bottom of the chart to find that a conductor between size No. 8 and No. 10 is required to prevent a greater drop than 1 volt. Since the indicated value is between two numbers, the larger size, No. 8, should be selected. This is the smallest size which should be used to avoid an excessive voltage drop.

To determine that the conductor size is sufficient to preclude overheating, disregard both the numbers along the left side of the chart and the horizontal lines. Assume that the conductor is to be a single wire in free air carrying continuous current. Place a pointer at the top of the table on the diagonal line numbered 20 amperes. Follow this line until the pointer intersects the diagonal line marked "curve 2." Drop the pointer straight down to the bottom of the chart. This point is between numbers 16 and 18. The larger size, No. 16, should be selected. This is the smallest-size conductor acceptable for carrying 20-ampere current in a single wire in free air without overheating.

If the installation is for equipment having only an intermittent (Max. 2 min.) requirement for power, the chart in figure 4–84 is used in the same manner.

Conductor Insulation

Two fundamental properties of insulation materials (for example, rubber, glass, asbestos, and plastic) are insulation resistance and dielectric strength. These are entirely different and distinct properties.

Insulation resistance is the resistance to current leakage through and over the surface of insulation materials. Insulation resistance can be measured with a megger without damaging the insulation, and data so obtained serves as a useful guide in determining the general condition of insulation. However, the data obtained in this manner may not give a true picture of the condition of the insulation. Clean, dry insulation having cracks or other faults

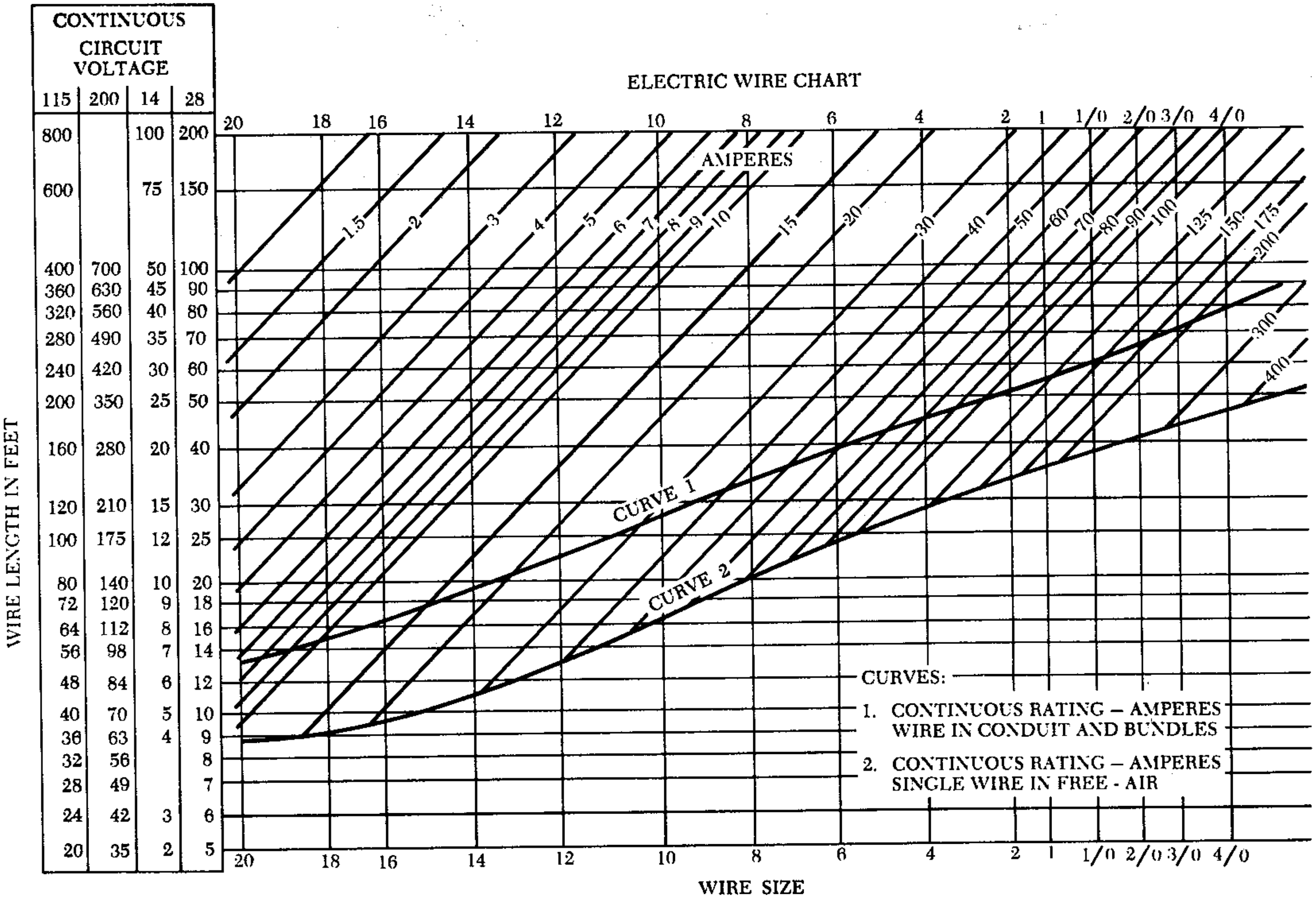


FIGURE 4–84. Conductor chart, continuous rating. (Applicable to copper conductors.)

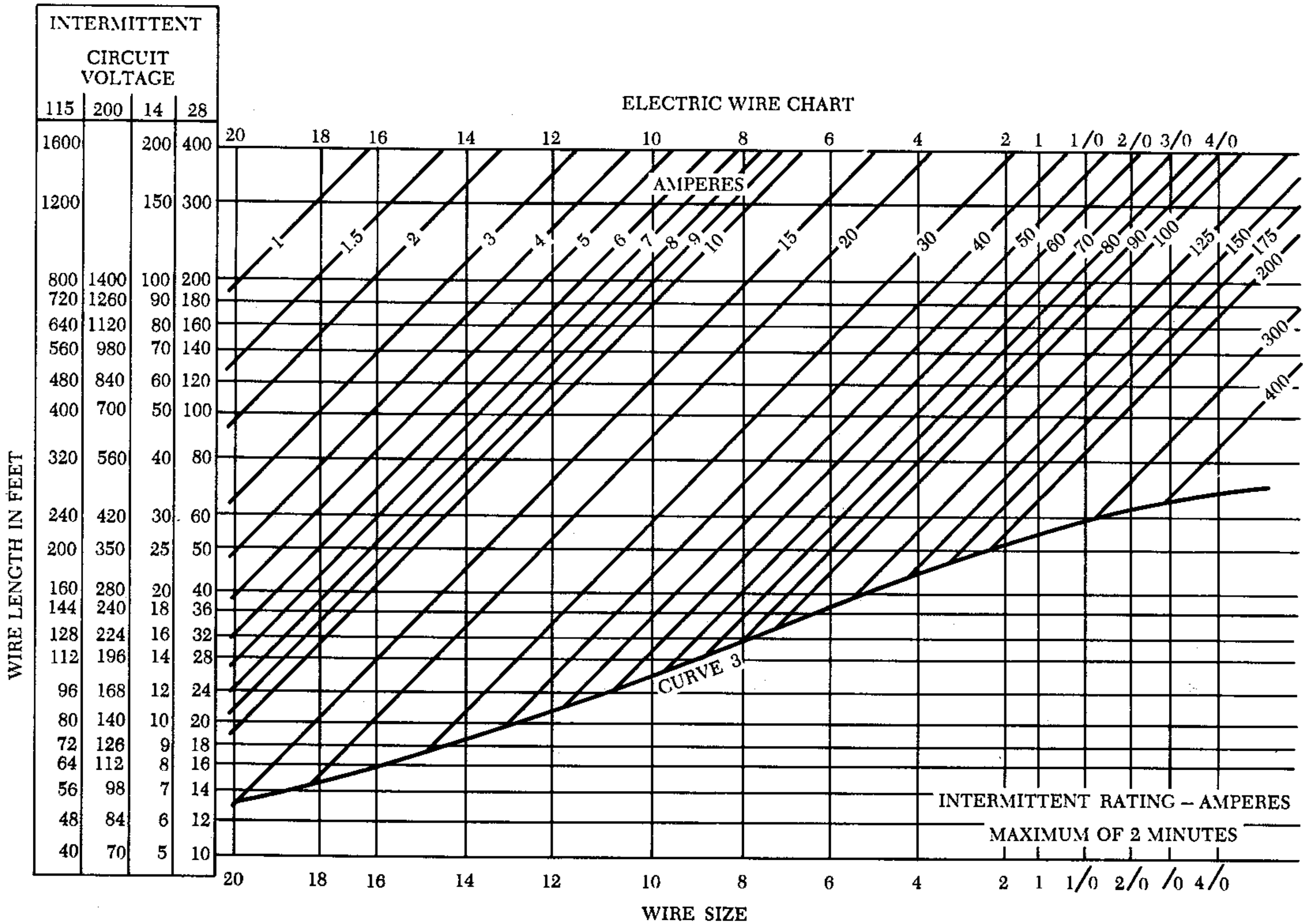


FIGURE 4–85. Conductor chart, intermittent rating. (Applicable to copper conductors.)

may show a high value of insulation resistance but would not be suitable for use.

Dielectric strength is the ability of the insulator to withstand potential difference and is usually expressed in terms of the voltage at which the insulation fails because of the electrostatic stress. Maximum dielectric strength values can be measured by raising the voltage of a test sample until the insulation breaks down.

Because of the expense of insulation and its stiffening effect, together with the great variety of physical and electrical conditions under which the conductors are operated, only the necessary minimum insulation is applied for any particular type of cable designed to do a specific job.

The type of conductor insulation material varies with the type of installation. Such types of insulation as rubber, silk, and paper are no longer used extensively in aircraft systems. More common today are such materials as vinyl, cotton, nylon, Teflon, and Rockbestos.

Identifying Wire and Cable

To aid in testing and repair operations, many maintenance activities mark wire or cable with a combination of letters and numbers which identify the wire, the circuit it belongs to, the gage number, and other information necessary to relate the wire or cable to a wiring diagram. Such markings are called the identification code.

There is no standard procedure for marking and identifying wiring, each manufacturer normally develops his own identification code. Figure 4–86 illustrates one identification system and shows the usual spacing in marking a wire. The number 22 in the code refers to the system in which the wire is installed, e.g., the VHF system. The next set of numbers, 013, is the wire number, and 18 indicates the wire size.

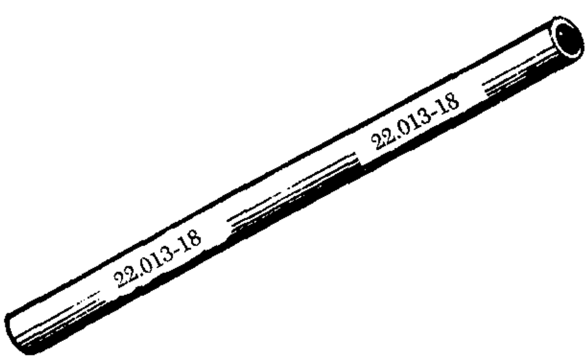


FIGURE 4–86. Wire identification code.

Some system components, especially plugs and jacks, are identified by a letter or group of letters and numbers added to the basic identification number. These letters and numbers may indicate the location of the component in the system. Interconnected cables are also marked in some systems to indicate location, proper termination, and use.

In any system, the marking should be legible, and the stamping color should contrast with the color of the wire insulation. For example, use black stamping with light-colored backgrounds, or white stamping on dark-colored backgrounds.

Most manufacturers mark the wires at intervals of not more than 15 in. lengthwise and within 3 in. of each junction or terminating point. Figure 4–87 shows wire identification at a terminal block.

Coaxial cable and wires at terminal blocks and junction boxes are often identified by marking or stamping a wiring sleeve rather than the wire itself. For general-purpose wiring, flexible vinyl sleeving, either clear or white opaque, is commonly used. For high-temperature applications, silicone rubber or silicone fiber glass sleeving is recommended. Where resistance to synthetic hydraulic fluids or other solvents is necessary, either clear or white opaque nylon sleeving can be used.

While the preferred method is to stamp the identification marking directly on the wire or on sleeving, other methods are often employed. Figure 4–88 shows two alternate methods. One method uses a marked sleeve tied in place. The other uses a pressure-sensitive tape.

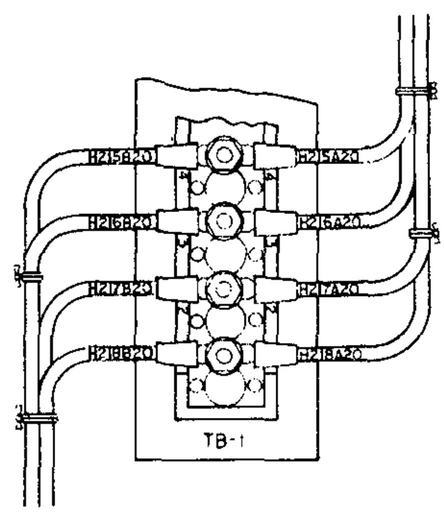


FIGURE 4–87. Wire identification at a terminal block.

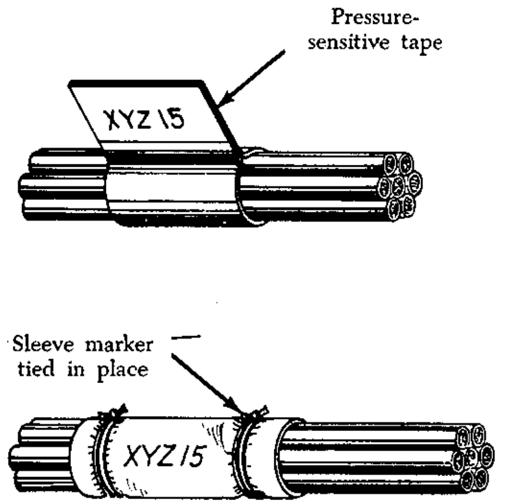


FIGURE 4–88. Alternate methods of identifying wire bundles.

Electrical Wiring Installation

The following recommended procedures for installing aircraft electrical wiring are typical of those used on most types of aircraft. For purposes of this discussion, the following definitions are applicable:

(1) Open wiring—any wire, wire group, or wire bundle not enclosed in conduit.

(2) Wire group—two or more wires going to the same location, tied together to retain identity of the group.

(3) Wire bundle—two or more wire groups tied together because they are going in the same direction at the point where the tie is located.

(4) Electrically protected wiring—wires which include (in the circuit) protections against overloading, such as fuses, circuit breakers, or other limiting devices.

(5) Electrically unprotected wiring—wires (generally from generators to main bus distribution points) which do not have protection, such as fuses, circuit breakers, or other current-limiting devices.

Wire Groups and Bundles

Grouping or bundling certain wires, such as electrically unprotected power wiring and wiring to duplicate vital equipment, should be avoided.

Wire bundles should generally be limited in size to a bundle of 75 wires, or 2 in. in diameter where practicable. When several wires are grouped at junction boxes, terminal blocks, panels, etc., identity of the group within a bundle can be retained as shown in figure 4–89.

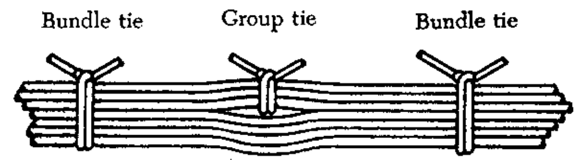


FIGURE 4–89. Group and bundle ties.

Twisting Wires

When specified on the engineering drawing, parallel wires must be twisted. The following are the most common examples:

(1) Wiring in the vicinity of magnetic compass or flux valve.

(2) Three-phase distribution wiring.

(3) Certain other wires (usually radio wiring).

Twist the wires so that they will lie snugly against each other, making approximately the number of twists per foot shown in table 4. Always check wire insulation for damage after twisting. If the insulation is torn or frayed, replace the wire.

TABLE 4. Recommended number of twists per foot.

	Wire Size									
	#22	#20	#18	#16	#14	#12	#10	#8	#6	#4
2 Wires	10	10	9	8	7½	7	6½	6	5	4
3 Wires	10	10	8½	7	6½	6	5½	5	4	3

Spliced Connections in Wire Bundles

Spliced connections in wire groups or bundles should be located so that they can be easily inspected. Splices should also be staggered (figure 4–90) so that the bundle does not become excessively enlarged. All noninsulated splices should be covered with plastic, securely tied at both ends.

Slack in Wiring Bundles

Single wires or wire bundles should not be installed with excessive slack. Slack between supports should normally not exceed 1/2 in. This is the maximum it should be possible to deflect the wire with normal hand force. However, this may be exceeded if the wire bundle is thin and the clamps are far apart. But the slack should never be so great that the wire bundle can abrade against any surface it touches. Figure 4–91 illustrates the proper slack for wires in bundles. A sufficient amount of slack should be allowed near each end of a bundle to:

(1) Permit easy maintenance.

(2) Allow replacement of terminals.

(3) Prevent mechanical strain on the wires, wire junctions, or supports.

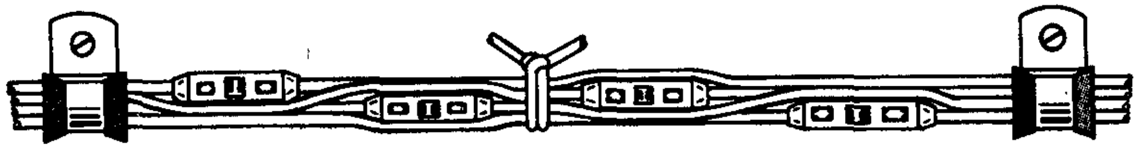


FIGURE 4–90. Staggered splices in wire bundle.

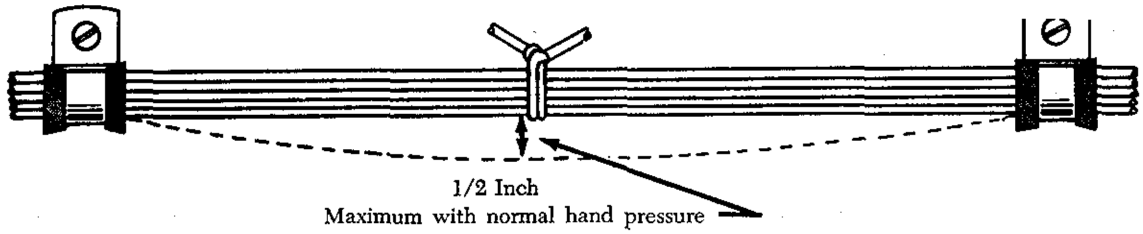


FIGURE 4–91. Slack in wire bundle between supports.

(4) Permit free movement of shock and vibration-mounted equipment.
(5) Permit shifting of equipment for purposes of maintenance.

Bend Radii

Bends in wire groups or bundles should not be less than 10 times the outside diameter of the wire group or bundle. However, at terminal strips, where wire is suitably supported at each end of the bend, a minimum radius of three times the outside diameter of the wire, or wire bundle, is normally acceptable. There are, of course, exceptions to these guidelines in the case of certain types of cable; for example, coaxial cable should never be bent to a smaller radius than six times the outside diameter.

Routing and Installation

All wiring should be installed so that it is mechanically and electrically sound and neat in appearance. Whenever practicable, wires and bundles should be routed parallel with, or at right angles to, the stringers or ribs of the area involved. An exception to this general rule is the coaxial cables, which are routed as directly as possible.

The wiring must be adequately supported throughout its length. A sufficient number of supports must be provided to prevent undue vibration of the unsupported lengths. All wires and wire groups should be routed and installed to protect them from:

(1) Chafing or abrasion.
(2) High temperature.
(3) Being used as handholds, or as support for personal belongings and equipment.
(4) Damage by personnel moving within the aircraft.
(5) Damage from cargo stowage or shifting.
(6) Damage from battery acid fumes, spray, or spillage.
(7) Damage from solvents and fluids.

Protection Against Chafing

Wires and wire groups should be installed so that they are protected against chafing or abrasion in those locations where contact with sharp surfaces or other wires would damage the insulation. Damage to the insulation can cause short circuits, malfunctions, or inadvertent operation of equipment. Cable clamps should be used to support wire bundles (figure 4–92 at each hole through a bulkhead. If wires come closer than 1/4 in. to the edge of the hole, a suitable grommet is used in the hole, as shown in figure 4–93.

Sometimes it is necessary to cut nylon or rubber grommets to facilitate installation. In these instances, after insertion, the grommet can be secured in place with general-purpose cement. The slot should be at the top of the hole, and the cut should be made at an angle of 45° to the axis of the wire bundle hole.

Protection Against High Temperature

To prevent insulation deterioration, wires should be kept separate from high-temperature equipment, such as resistors, exhaust stacks, heating ducts, etc. The amount of separation is normally specified by engineering drawings. Some wires must invariably be run through hot areas. These wires must be insulated with high-temperature material such as asbestos, fiber glass, or Teflon. Additional protection is also often required in the form of conduits. A low-temperature insulated wire should never be used to replace a high-temperature insulated wire.

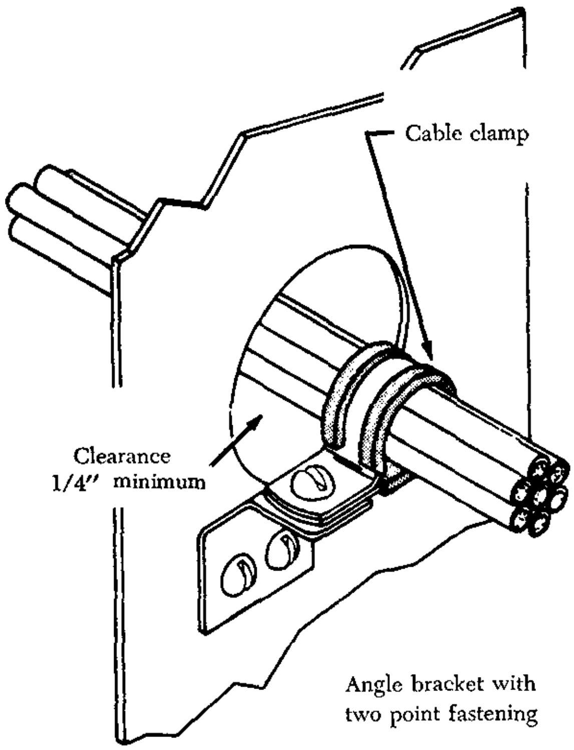


FIGURE 4–92. Cable clamp at bulkhead hole.

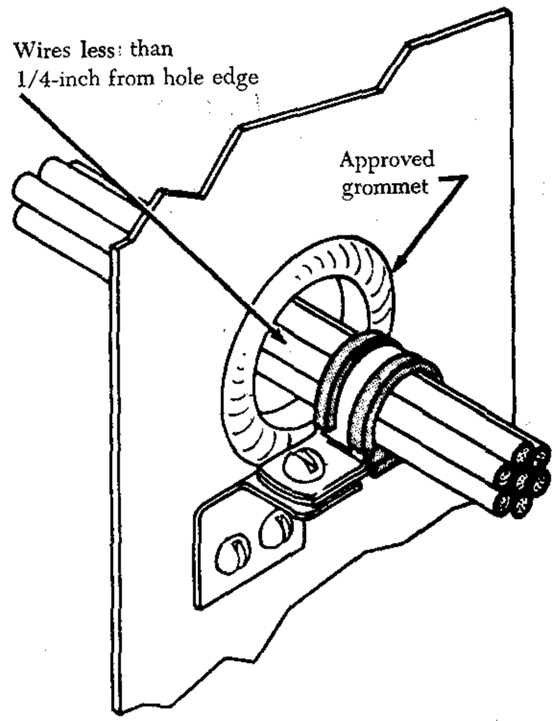


FIGURE 4–93. Cable clamp and grommet at bulkhead hole.

Many coaxial cables have soft plastic insulation, such as polyethylene, which is especially subject to deformation and deterioration at elevated temperatures. All high-temperature areas should be avoided when installing these cables.

Additional abrasion protection should be given to asbestos wires enclosed in conduit. Either conduit with a high-temperature rubber liner should be used, or asbestos wires can be enclosed individually in high-temperature plastic tubes before being installed in the conduit.

Protection Against Solvents and Fluids

Avoid installing wires in areas where they will be subjected to damage from fluids. Wires should not be placed in the lowest 4 inches of the aircraft fuselage, except those that must terminate in that area. If there is a possibility that wiring without a protective nylon outer jacket may be soaked with fluids, plastic tubing should be used to protect it. This tubing should extend past the exposure area in both directions and should be tied at each end. If the wire has a low point between the tubing ends, provide a 1/8 in. drainage hole, as shown in figure 4–94. This hole should be punched into the tubing after the installation is complete and the low point definitely established by using a hole punch to cut a half circle. Care should be taken not to damage any wires inside the tubing when using the punch.

Wire also should never be routed below a battery. All wires in the vicinity of a battery should be inspected frequently. Wires discolored by battery fumes should be replaced.

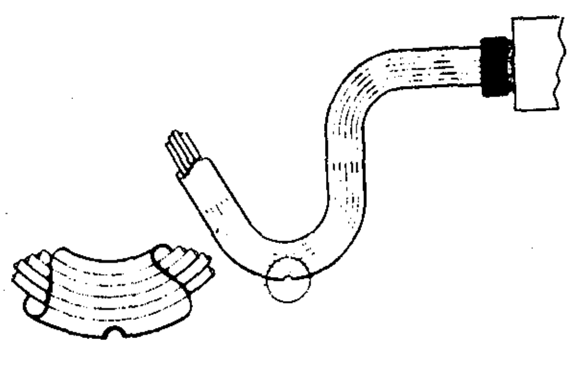


FIGURE 4–94. Drainage hole in low point of tubing.

Protection of Wires in Wheel Well Area

Wires located in wheel wells are subject to many additional hazards, such as exposure to fluids, pinching, and severe flexing in service. All wire bundles should be protected by sleeves of flexible tubing securely held at each end. There should be no relative movement at points where flexible tubing is secured. These wires and the insulating tubing should be inspected carefully at very frequent intervals, and wires or tubing should be replaced at the first sign of wear. There should be no strain on attachments when parts are fully extended, but slack should not be excessive.

Routing Precautions

When wiring must be routed parallel to combustible fluid or oxygen lines for short distances, as much separation as possible should be maintained. The wires should be on a level with, or above, the plumbing lines. Clamps should be spaced so that if a wire is broken at a clamp, it will not contact the line. Where a 6 in. separation is not possible, both the wire bundle and the plumbing line can be clamped to the same structure to prevent any relative motion. If the separation is less than 2 in. but more than 1/2 in., two cable clamps back-to-back (figure 4–95) can be used to maintain a rigid separation only, and not for support of the bundle. No wire should be routed so that it is located nearer than 1/2 in. to a plumbing line. Neither should a wire or wire bundle be supported from a plumbing line that carries flammable fluids or oxygen.

Wiring should be routed to maintain a minimum clearance of at least 3 in. from control cables. If this cannot be accomplished, mechanical guards should be installed to prevent contact between wiring and control cables.

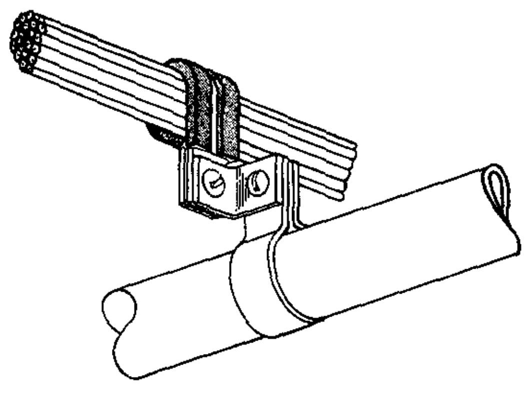


FIGURE 4–95. Separation of wires from plumbing lines.

Installation of Cable Clamps

Cable clamps should be installed with regard to the proper mounting angle (figure 4–96). The mounting screw should be above the wire bundle. It is also desirable that the back of the cable clamp rest against a structural member where practicable.

Figure 4–97 shows some typical mounting hardware used in installing cable clamps.

Be sure that wires are not pinched in cable clamps. Where possible, mount them directly to structural members, as shown in figure 4–98.

Clamps can be used with rubber cushions to secure wire bundles to tubular structures as shown in figure 4–99. Such clamps must fit tightly but should not be deformed when locked in place.

LACING AND TYING WIRE BUNDLES

Wire groups and bundles are laced or tied with cord to provide ease of installation, maintenance, and inspection. This section describes and illustrates recommended procedures for lacing and tying wires with knots which will hold tightly under all conditions. For the purposes of this discussion, the following terms are defined:

(1) Tying is the securing together of a group or bundle of wires by individual pieces of cord tied around the group or bundle at regular intervals.

(2) Lacing is the securing together of a group or bundle of wires by a continuous piece of cord forming loops at regular intervals around the group or bundle.

(3) A wire group is two or more wires tied or laced together to give identity to an individual system.

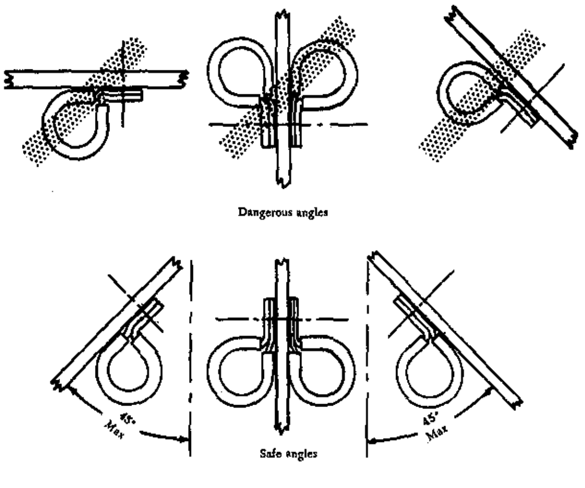


FIGURE 4–96. Proper mounting angle for cable clamps.

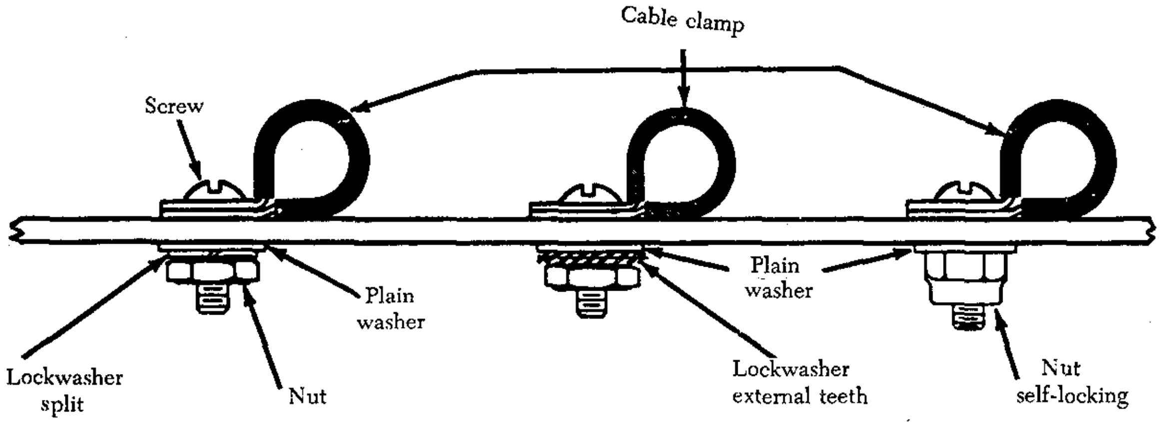


FIGURE 4–97. Typical mounting hardware for cable clamps.

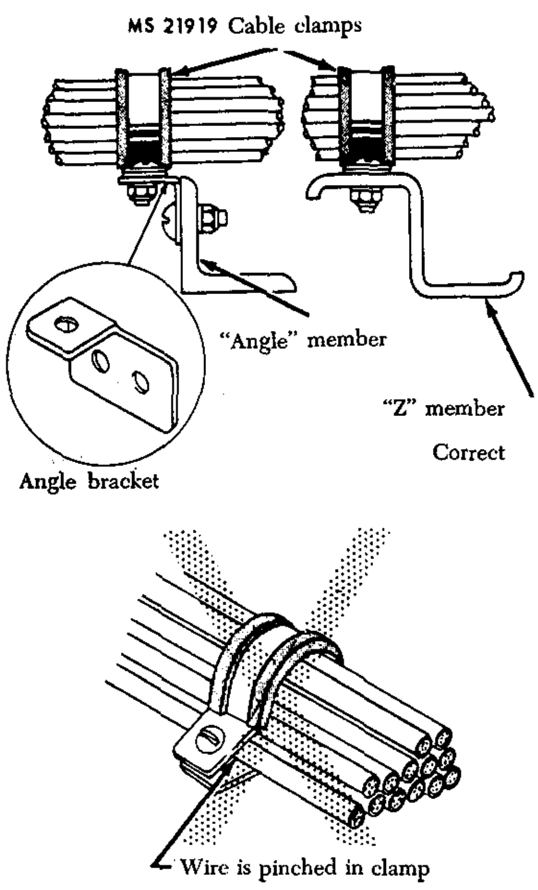


FIGURE 4–98. Mounting cable clamp to structure.

(4) A wire bundle is two or more wires or groups tied or laced together to facilitate maintenance.

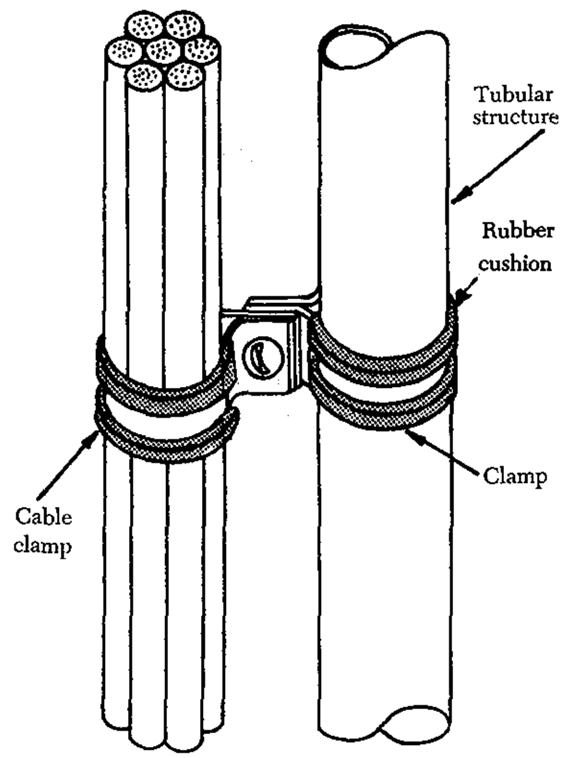


FIGURE 4–99. Installing cable clamp to tubular structure.

The material used for lacing and tying is either cotton or nylon cord. Nylon cord is moisture- and fungus-resistant, but cotton cord must be waxed before using to give it these necessary protective characteristics.

Single-Cord Lacing

Figure 4–100 shows the steps in lacing a wire bundle with a single cord. The lacing procedure is started at the thick end of the wire group or bundle with a knot consisting of a clove hitch with an extra loop. The lacing is then continued at regular intervals with half hitches along the wire group or bundle and at each point where a wire or wire group branches off. The half hitches should be spaced so that the bundle is neat and secure. The lacing is ended by tying a knot consisting of a clove hitch with an extra loop. After the knot is tied, the free ends of the lacing cord should be trimmed to approximately 3/8 in.

Double-Cord Lacing

Figure 4–101 illustrates the procedure for double-cord lacing. The lacing is started at the thick end of the wire group or bundle with a bowline-on-a-bight knot (A of figure 4–101). At regular intervals along the wire group or bundle, and at each point where a wire branches off, the lacing is continued using half hitches, with both cords held firmly together. The half hitches should be spaced so that the group or bundle is neat and secure. The lacing is ended with a knot consisting of a half hitch, continuing one of the cords clockwise and the other counterclockwise and then tying the cord ends with a square knot. The free ends of the lacing cord should be trimmed to approximately 3/8 in.

Lacing Branch-Offs

Figure 4–102 illustrates a recommended procedure for lacing a wire group that branches off the main wire bundle. The branch-off lacing is started with a knot located on the main bundle just past the branch-off point. Continue the lacing along the branched-off wire group, using regularly spaced half hitches. If a double cord is used, both cords should be held snugly together. The half hitches should be spaced to lace the bundle neatly and securely. End the lacing with the regular terminal knot used in single- or double-cord lacing, as applicable, and trim the free ends of the lacing cord neatly.

Tying

All wire groups or bundles should be tied where supports are more than 12 in. apart. Ties are made using waxed cotton cord, nylon cord, or fiber glass cord. Some manufacturers permit the use of pressure-sensitive vinyl electrical tape. When permitted, the tape should be wrapped three turns around the bundle and the ends heat sealed to prevent unwinding of the tape. Figure 4–103

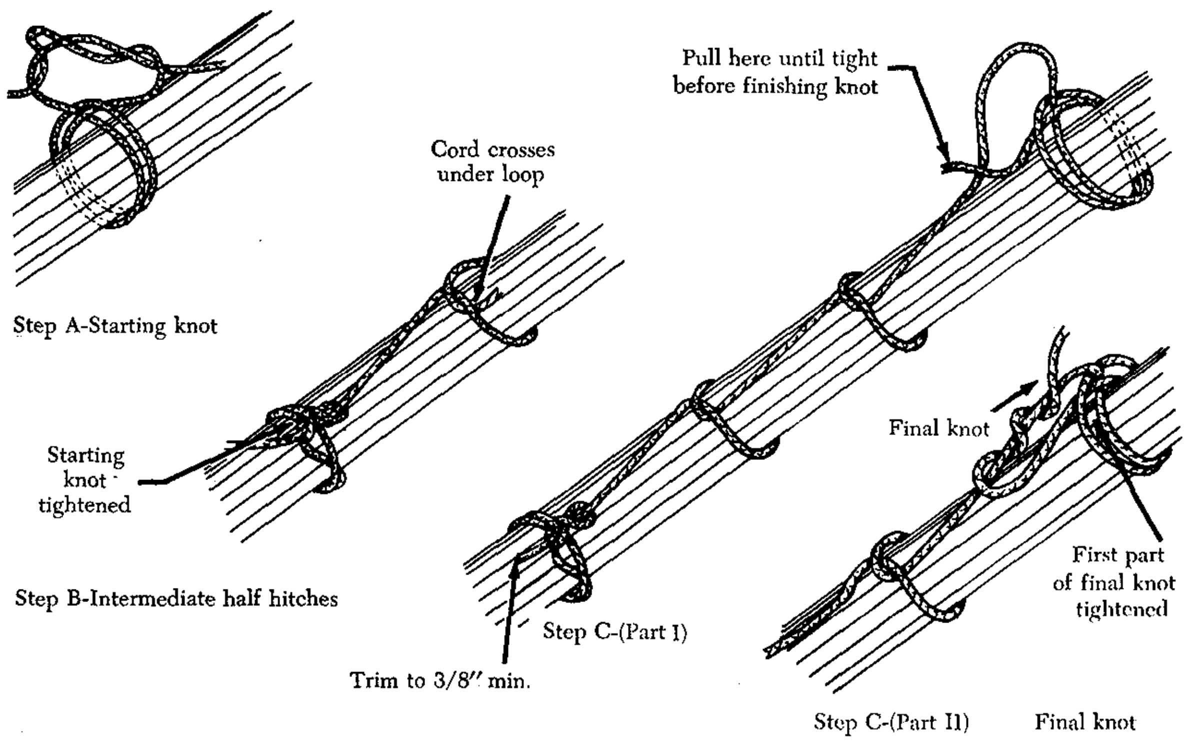


FIGURE 4–100. Single-cord lacing.

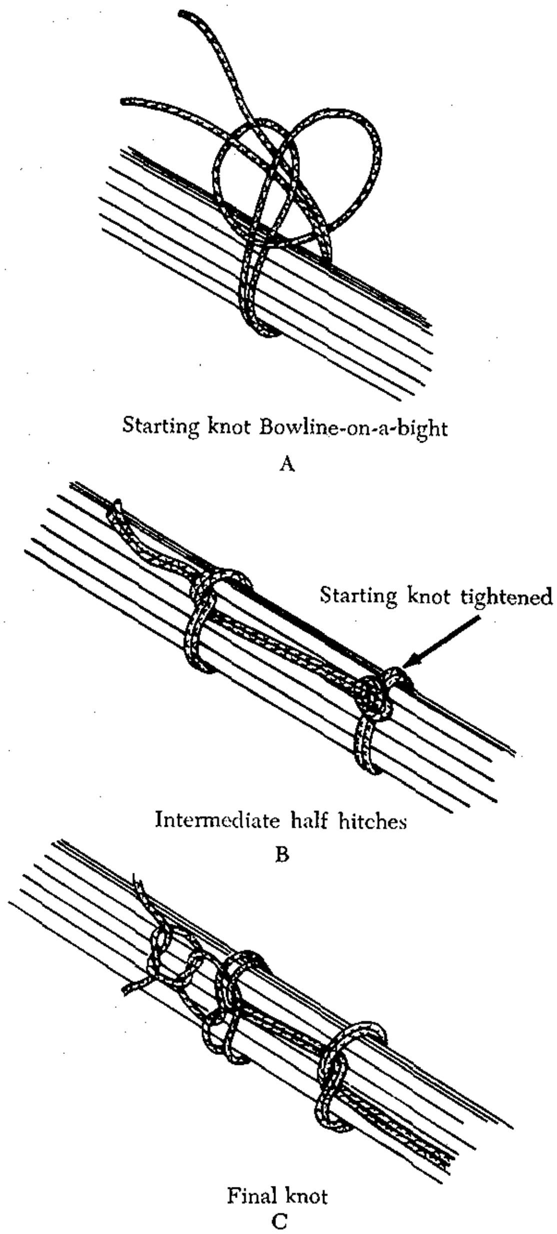


FIGURE 4–101. Double-cord lacing.

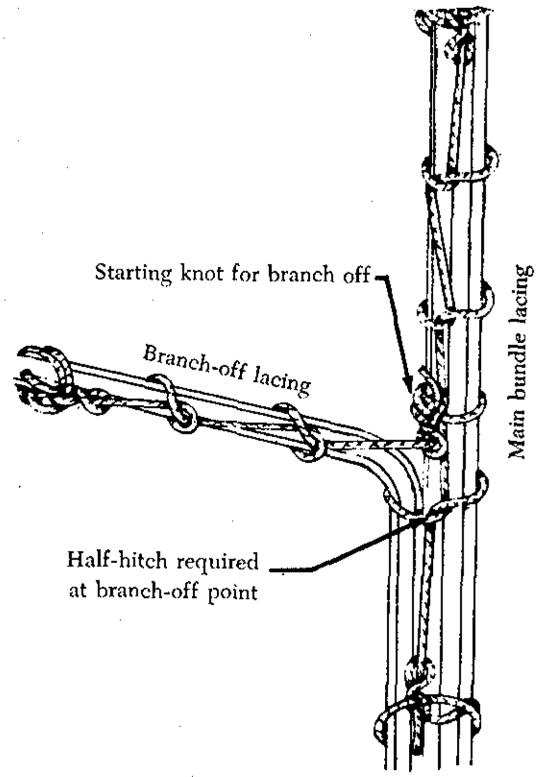


FIGURE 4–102. Lacing a branch-off.

illustrates a recommended procedure for tying a wire group or bundle. The tie is started by wrapping the cord around the wire group to tie a clove-hitch knot. Then a square knot with an extra loop is tied and the free ends of the cord trimmed.

Temporary ties are sometimes used in making up and installing wire groups and bundles. Colored cord is normally used to make temporary ties, since they are removed when the installation is complete.

Whether lacing or tying, bundles should be secured tightly enough to prevent slipping, but not so tightly that the cord cuts into or deforms the insulation. This applies especially to coaxial cable, which has a soft dielectric insulation between the inner and outer conductor. Coxial cables have been damaged by the use of lacing materials or by methods of lacing or tying wire bundles which cause a concentrated force on the cable insulation. Elastic lacing materials, small diameter lacing cord, and excessive tightening deform the interconductor insulation and result in short circuits or impedance changes. Flat nylon braided waxed lacing tape should be used for lacing or tying any wire bundles containing coaxial cables.

The part of a wire group or bundle located inside a conduit is not tied or laced, but wire groups or bundles inside enclosures, such as junction boxes, should be laced only.

CUTTING WIRE AND CABLE

To make installation, maintenance, and repair easier, runs of wire and cable in aircraft are broken at specified locations by junctions, such as connectors, terminal blocks, or buses. Before assembly to these junctions, wires and cables must be cut to length.

All wires and cables should be cut to the lengths specified on drawings and wiring diagrams. The cut should be made clean and square, and the wire or cable should not be deformed. If necessary, large-diameter wire should be re-shaped after cutting. Good cuts can be made only if the blades of cutting tools are sharp and free from nicks. A dull blade will deform and extrude wire ends.

STRIPPING WIRE AND CABLE

Nearly all wire and cable used as electrical conductors are covered with some type of insulation. In order to make electrical connections with the wire, a part of this insulation must be removed to expose the bare conductor.

Copper wire can be stripped in a number of ways depending on the size and insulation. Table 5 lists some types of stripping tools recommended for various wire sizes and types of insulation.

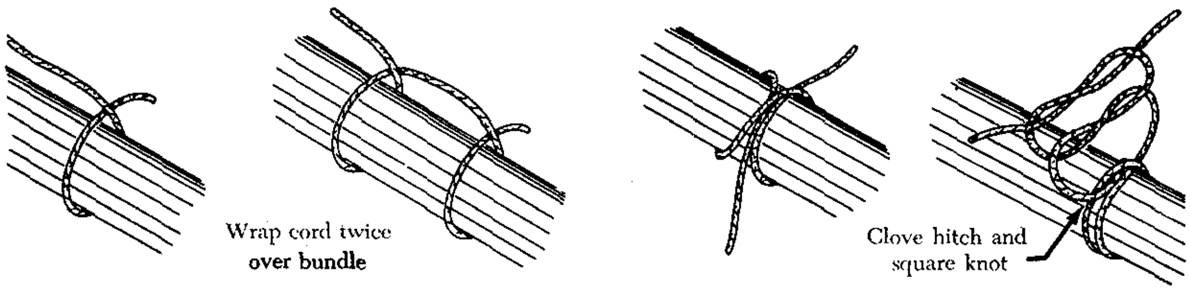


FIGURE 4–103. Tying a wire group or bundle.

TABLE 5. Wire strippers for copper wire.

Stripper	*Wire Size*	*Insulations*
Hot-blade	#26 — #4	All except asbestos
Rotary, electric	#26 — #4	All
Bench	#20 — #6	All
Hand pliers	#26 — #8	All
Knife	#2 — #0000	All

Aluminum wire must be stripped using extreme care, since individual strands will break very easily after being nicked.

The following general precautions are recommended when stripping any type of wire:

(1) When using any type of wire stripper, hold the wire so that it is perpendicular to the cutting blades.

(2) Adjust automatic stripping tools carefully; follow the manufacturer's instructions to avoid nicking, cutting, or otherwise damaging strands. This is especially important for aluminum wires and for copper wires smaller than No. 10. Examine stripped wires for damage. Cut off and re-strip (if length is sufficient), or reject and replace any wires with more than the allowable number of nicked or broken strands listed in the manufacturer's instructions.

(3) Make sure insulation is clean-cut with no frayed or ragged edges. Trim if necessary.

(4) Make sure all insulation is removed from stripped area. Some types of wires are supplied with a transparent layer of insulation between the conductor and the primary insulation. If this is present, remove it.

(5) When using hand-plier strippers to remove lengths of insulation longer than 3/4 in., it is easier to accomplish in two or more operations.

(6) Re-twist copper strands by hand or with pliers if necessary to restore natural lay and tightness of strands.

A pair of hand wire strippers is shown in figure 4–104. This tool is commonly used to strip most types of wire.

The following general procedures describe the steps for stripping wire with a hand stripper. (Refer to figure 4–105.)

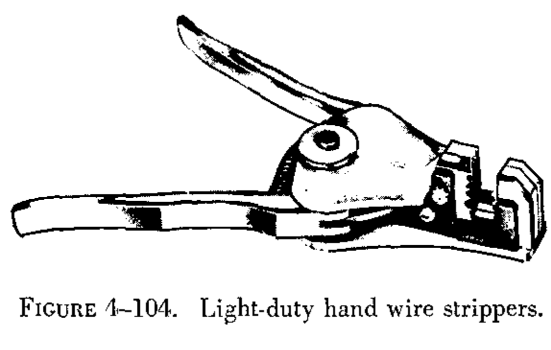


FIGURE 4–104. Light-duty hand wire strippers.

(1) Insert wire into exact center of correct cutting slot for wire size to be stripped. Each slot is marked with wire size.
(2) Close handles together as far as they will go.
(3) Release handles, allowing wire holder to return to the "open" position.
(4) Remove stripped wire.

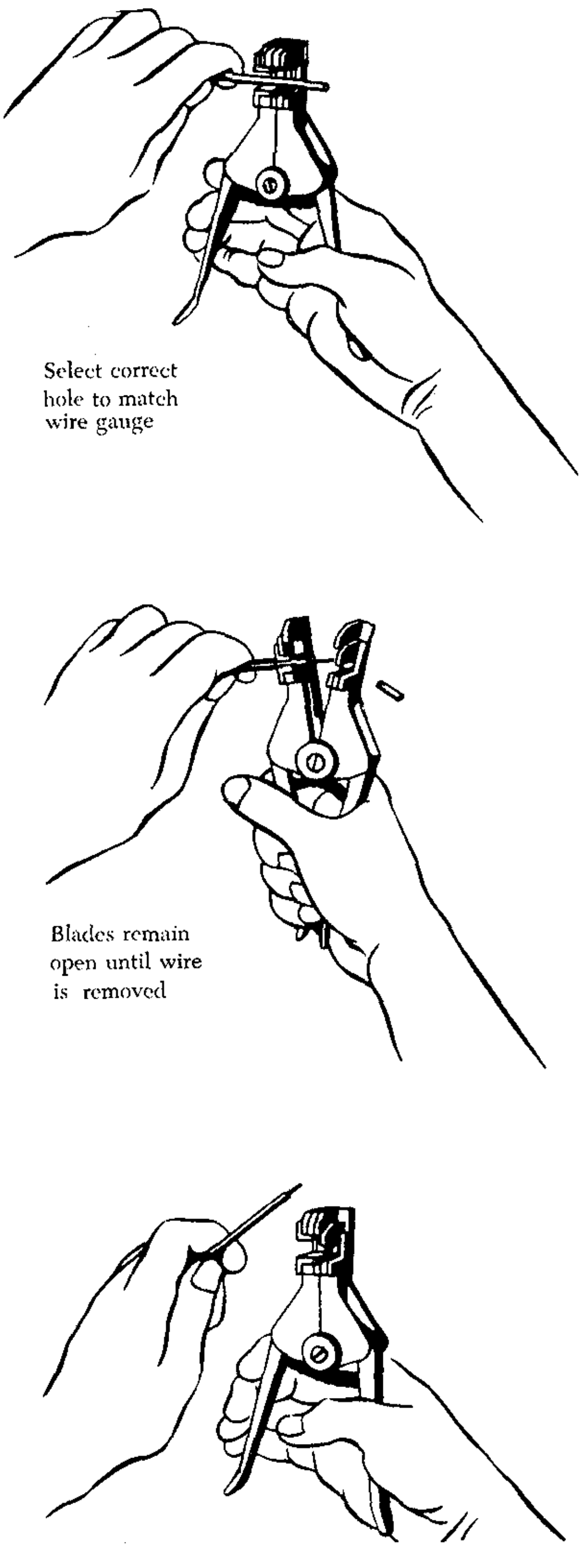


FIGURE 4–105. Stripping wire with hand stripper.

Solderless Terminals and Splices

Splicing of electrical cable should be kept to a minimum and avoided entirely in locations subject to extreme vibrations. Individual wires in a group or bundle can usually be spliced, provided the completed splice is located so that it can be inspected periodically. The splices should be staggered so that the bundle does not become excessively enlarged. Many types of aircraft splice connectors are available for splicing individual wires. Self-insulated splice connectors are usually preferred; however, a noninsulated splice connector can be used if the splice is covered with plastic sleeving secured at both ends. Solder splices may be used, but they are particularly brittle and not recommended.

Electric wires are terminated with solderless terminal lugs to permit easy and efficient connection to and disconnection from terminal blocks, bus bars, or other electrical equipment. Solderless splices join electric wires to form permanent continuous runs. Solderless terminal lugs and splices are made of copper or aluminum and are preinsulated or uninsulated, depending on the desired application.

Terminal lugs are generally available in three types for use in different space conditions. These are the flag, straight, and right-angle lugs. Terminal lugs are "crimped" (sometimes called "staked" or "swaged") to the wires by means of hand or power crimping tools.

The following discussion describes recommended methods for terminating copper and aluminum wires using solderless terminal lugs. It also describes the method for splicing copper wires using solderless splices.

Copper Wire Terminals

Copper wires are terminated with solderless, preinsulated straight copper terminal lugs. The insulation is part of the terminal lug and extends beyond its barrel so that it will cover a portion of the wire insulation, making the use of an insulation sleeve unnecessary (figure 4–106).

In addition, preinsulated terminal lugs contain an insulation grip (a metal reinforcing sleeve) beneath the insulation for extra gripping strength on the wire insulation. Preinsulated terminals accommodate more than one size of wire; the insulation is usually

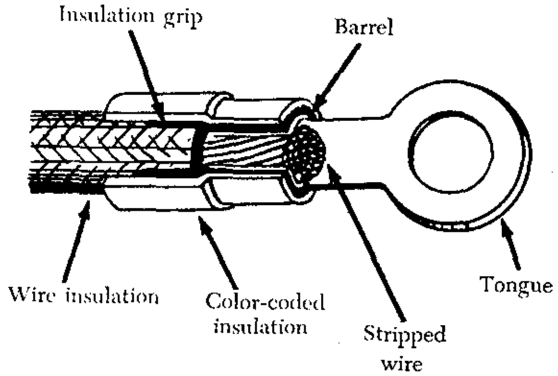


FIGURE 4–106. Preinsulated terminal lug.

color-coded to identify the wire sizes that can be terminated with each of the terminal lug sizes.

Crimping Tools

Hand, portable power, and stationary power tools are available for crimping terminal lugs. These tools crimp the barrel of the terminal lug to the conductor and simultaneously crimp the insulation grip to the wire insulation.

Hand crimping tools all have a self-locking ratchet that prevents opening the tool until the crimp is complete. Some hand crimping tools are equipped with a nest of various size inserts to fit different size terminal lugs. Others are used on one terminal lug size only. All types of hand crimping tools are checked by gages for proper adjustment of crimping jaws.

Figure 4–107 shows a terminal lug inserted into a hand tool. The following general guidelines outline the crimping procedure:

(1) Strip the wire insulation to proper length.
(2) Insert the terminal lug, tongue first, into the hand tool barrel crimping jaws until the terminal lug barrel butts flush against the tool stop.
(3) Insert the stripped wire into the terminal lug barrel until the wire insulation butts flush against the end of the barrel.
(4) Squeeze the tool handles until the ratchet releases.
(5) Remove the completed assembly and examine it for proper crimp.

Some types of uninsulated terminal lugs are insulated after assembly to a wire by means of pieces of transparent flexible tubing called "sleeves." The sleeve provides electrical and mechanical protection at the connection. When the size of the sleeving used is such that it will fit tightly over the terminal lug, the sleeving need not be tied; otherwise, it should be tied with lacing cord (figure 4–108).

Aluminum Wire Terminals

Aluminum wire is being used increasingly in aircraft systems because of its weight advantage over copper. However, bending aluminum will cause "work hardening" of the metal, making it brittle. This results in failure or breakage of strands much sooner than in a similar case with copper wire. Aluminum also forms a high-resistant oxide film immediately upon exposure to air. To compensate for these disadvantages, it is important to use the most reliable installation procedures.

Only aluminum terminal lugs are used to terminate aluminum wires. They are generally available in three types: (1) Straight, (2) right-angle, and (3) flag. All aluminum terminals incorporate an inspection hole (figure 4–108) which permits check-

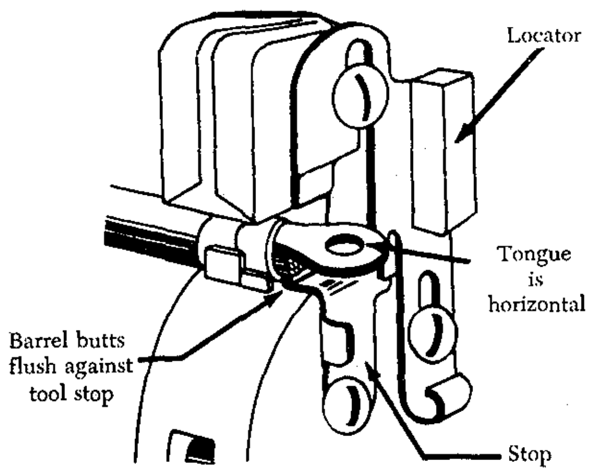


FIGURE 4–107. Inserting terminal lug into hand tool.

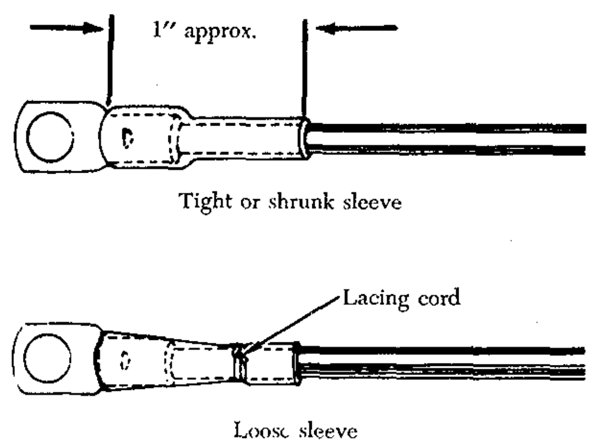


FIGURE 4–108. Insulating sleeves.

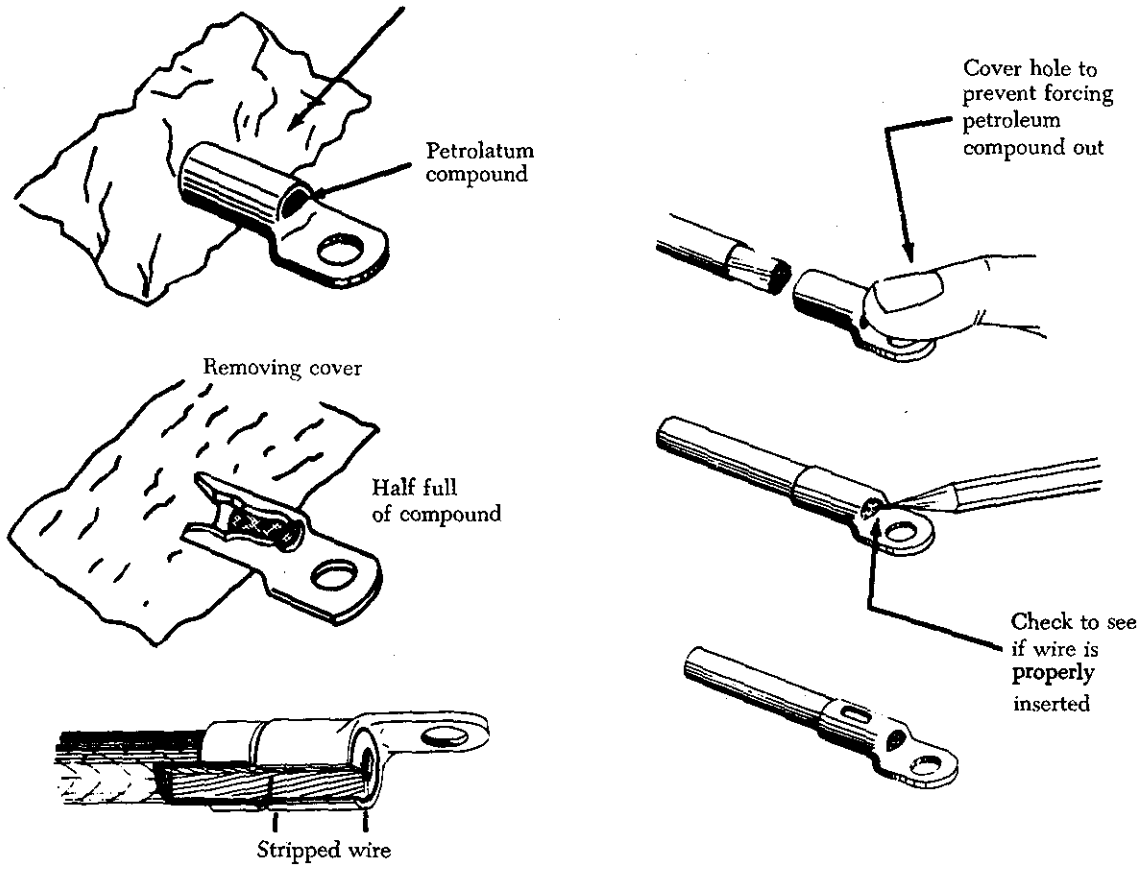


FIGURE 4–109. Inserting aluminum wire into aluminum terminal lugs.

ing the depth of wire insertion. The barrel of aluminum terminal lugs is filled with a petrolatum-zinc dust compound. This compound removes the oxide film from the aluminum by a grinding process during the crimping operation. The compound will also minimize later oxidation of the completed connection by excluding moisture and air. The compound is retained inside the terminal lug barrel by a plastic or foil seal at the end of the barrel.

Splicing Copper Wires Using Preinsulated Wires

Preinsulated permanent copper splices join small wires of sizes 22 through 10. Each splice size can be used for more than one wire size. Splices are usually color-coded in the same manner as pre-insulated, small copper terminal lugs. Some splices are insulated with white plastic. Splices are also used to reduce wire sizes as shown in figure 4–110.

Crimping tools are used to accomplish this type of splice. The crimping procedures are the same as those used for terminal lugs, except that the crimping operation must be done twice, one for each end of the splice.

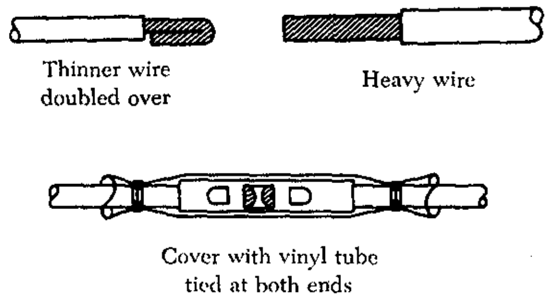


FIGURE 4–110. Reducing wire size with a permanent splice.

EMERGENCY SPLICING REPAIRS

Broken wires can be repaired by means of crimped splices, by using terminal lugs from which the tongue has been cut off, or by soldering together and potting broken strands. These repairs are applicable to copper wire. Damaged aluminum wire must not be temporarily spliced. These repairs are for temporary emergency use only and should be replaced as soon as possible with permanent repairs. Since some manufacturers prohibit splicing, the applicable manufacturer's instructions should always be consulted.

Splicing with Solder and Potting Compound

When neither a permanent splice nor a terminal lug is available, a broken wire can be repaired as follows (see figure 4-111):

(1) Install a piece of plastic sleeving about 3 in. long, and of the proper diameter to fit loosely over the insulation, on one piece of the broken wire.
(2) Strip approximately 1-1/2 in. from each broken end of the wire.
(3) Lay the stripped ends side by side and twist one wire around the other with approximately four turns.
(4) Twist the free end of the second wire around the first wire with approximately four turns. Solder the wire turns together, using 60/40 tin-lead resin-core solder.
(5) When solder is cool, draw the sleeve over the soldered wires and tie at one end. If potting compound is available, fill the sleeve with potting material and tie securely.
(6) Allow the potting compound to set without touching for 4 hrs. Full cure and electrical characteristics are achieved in 24 hrs.

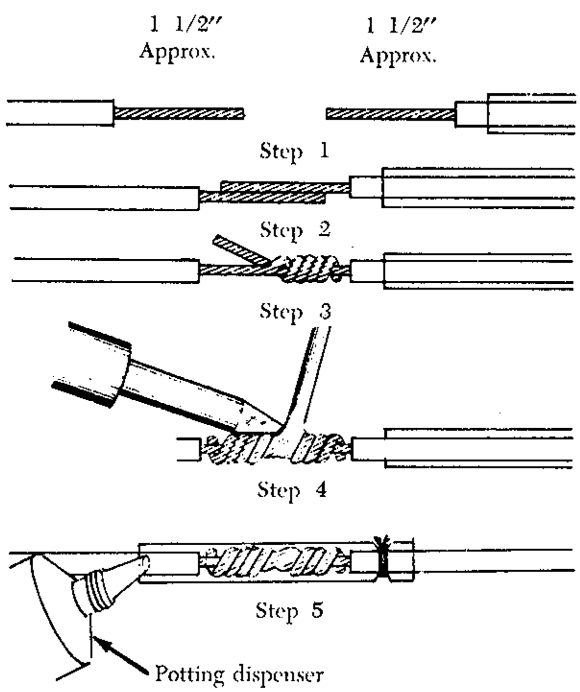


FIGURE 4–111. Repairing broken wire by soldering and potting.

CONNECTING TERMINAL LUGS TO TERMINAL BLOCKS

Terminal lugs should be installed on terminal blocks in such a manner that they are locked against movement in the direction of loosening (figure 4–112).

Terminal blocks are normally supplied with studs secured in place by a plain washer, an external tooth lockwasher, and a nut. In connecting terminals, a recommended practice is to place copper terminal lugs directly on top of the nut, followed with a plain washer and elastic stop nut, or with a plain washer, split steel lockwasher, and plain nut.

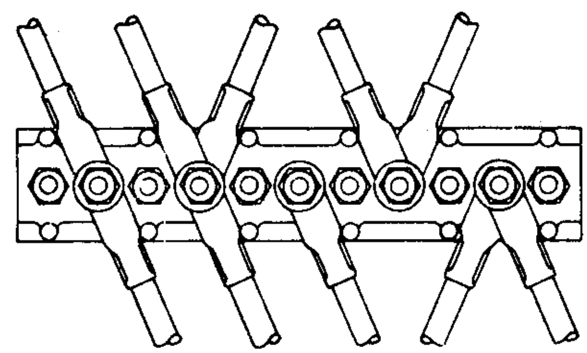


FIGURE 4–112. Connecting terminals to terminal block.

Aluminum terminal lugs should be placed over a plated brass plain washer, followed with another plated brass plain washer, split steel lockwasher, and plain nut or elastic stop nut. The plated brass washer should have a diameter equal to the tongue width of the aluminum terminal lug. Consult the manufacturer's instructions for recommended dimensions of these plated brass washers. Do not place any washer in the current path between two aluminum terminal lugs or between two copper terminal lugs. Also, do not place a lockwasher directly against the tongue or pad of the aluminum terminal.

To join a copper terminal lug to an aluminum terminal lug, place a plated brass plain washer over the nut which holds the stud in place; follow with the aluminum terminal lug, a plated brass plain washer, the copper terminal lug, plain washer, split steel lockwasher and plain nut or self-locking, all metal nut. As a general rule use a torque wrench to tighten nuts to ensure sufficient contact pressure. Manufacturer's instructions provide installation torques for all types of terminals.

BONDING AND GROUNDING

Bonding is the electrical connecting of two or more conducting objects not otherwise connected adequately. Grounding is the electrical connecting of a conducting object to the primary structure for return of current. Primary structure is the main frame, fuselage, or wing structure of the aircraft. Bonding and grounding connections are made in aircraft electrical systems to:

(1) Protect aircraft and personnel against hazards from lightning discharge.
(2) Provide current return paths.
(3) Prevent development of radio-frequency potentials.
(4) Protect personnel from shock hazard.
(5) Provide stability of radio transmission and reception.
(6) Prevent accumulation of static charge.

General Bonding and Grounding Procedures

The following general procedures and precautions are recommended when making bonding or grounding connections.

(1) Bond or ground parts to the primary aircraft structure where practicable.
(2) Make bonding or grounding connections in such a manner that no part of the aircraft structure is weakened.
(3) Bond parts individually if possible.
(4) Install bonding or grounding connections against smooth, clean surfaces.
(5) Install bonding or grounding connections so that vibration, expansion or contraction, or relative movement in normal service will not break or loosen the connection.
(6) Install bonding and grounding connections in protected areas whenever possible.

Bonding jumpers should be kept short as practicable, and installed in such a manner that the resistance of each connection does not exceed 0.003 ohm. The jumper should not interfere with the operation of movable aircraft elements, such as surface controls; normal movement of these elements should not result in damage to the bonding jumper.

To be sure a low-resistance connection has been made, nonconducting finishes, such as paint and anodizing films, should be removed from the surface to be contacted by the bonding terminal.

Electrolytic action can rapidly corrode a bonding connection if suitable precautions are not observed. Aluminum alloy jumpers are recommended for most cases; however, copper jumpers can be used to bond together parts made of stainless steel, cadmium-plated steel, copper, brass, or bronze. Where contact between dissimilar metals cannot be avoided, the choice of jumper and hardware should be such that corrosion is minimized, and the part most likely to corrode will be the jumper or associated hardware. Parts A and B of figure 4–113 illustrate some proper hardware combinations for making bonding connections. At locations where finishes are removed, a protective finish should be applied to the completed connection to prevent corrosion.

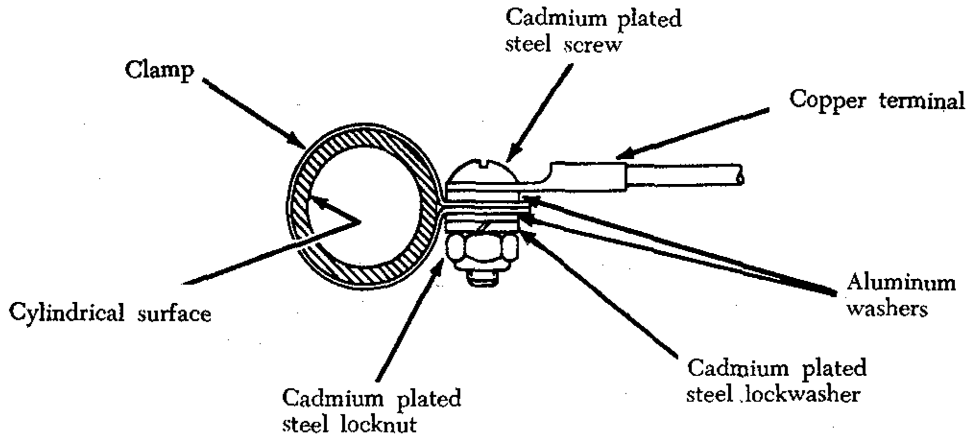
The use of solder to attach bonding jumpers should be avoided. Tubular members should be bonded by means of clamps to which the jumper is attached. The proper choice of clamp material minimizes the probability of corrosion. When bonding jumpers carry a substantial amount of ground return current, the current rating of the jumper should be adequate, and it should be determined that a negligible voltage drop is produced.

Bonding and grounding connections are normally made to flat surfaces by means of through-bolts or screws where there is easy access for installation. The three general types of bolted connections are:

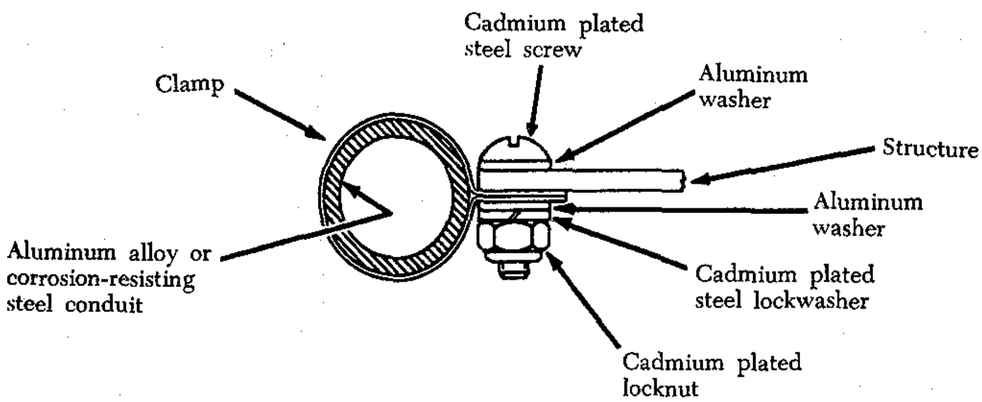
(1) In making a stud connection (figure 4–114), a bolt or screw is locked securely to the structure, thus becoming a stud. Grounding or bonding jumpers can be removed or added to the shank of the stud without removing the stud from the structure.
(2) Nut-plates are used where access to the nut for repairs is difficult. Nut-plates (figure 4–115) are riveted or welded to a clean area of the structure.

Bonding and grounding connections are also made to a tab (figure 4–115) riveted to a structure. In such cases it is important to clean the bonding or grounding surface and make the connection as though the connection were being made to the structure. If it is necessary to remove the tab for any reason, the rivets should be replaced with rivets one size larger, and the mating surfaces of the structure and the tab should be clean and free of anodic film.

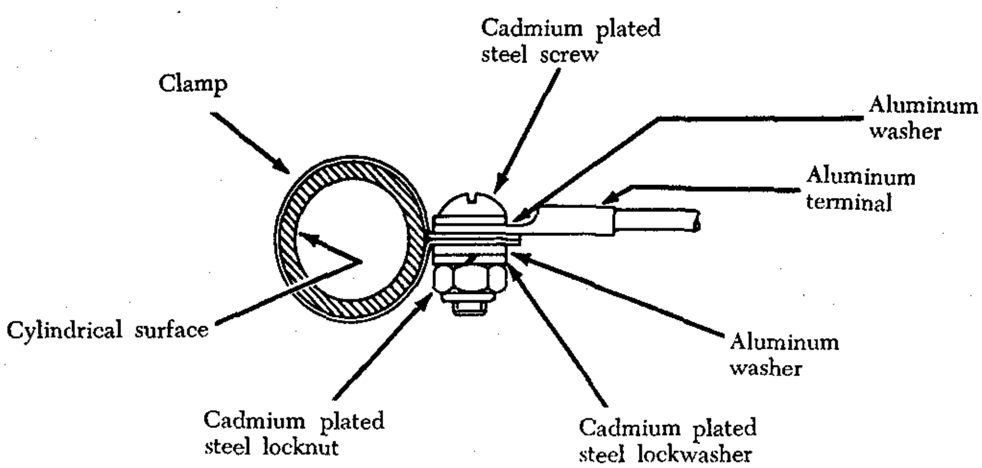
Bonding or grounding connections can be made to aluminum alloy, magnesium, or corrosion-resistant steel tubular structure as shown in figure 4–116, which shows the arrangement of hardware for bonding with an aluminum jumper. Because of the ease with which aluminum is deformed, it is necessary to distribute screw and nut pressure by means of plain washers.



A. Copper jumper connection to tubular structure.



B. Bonding conduit to structure.



C. Aluminum jumper connection to tubular structure.

FIGURE 4–113. Hardware combinations used in making bonding connections.

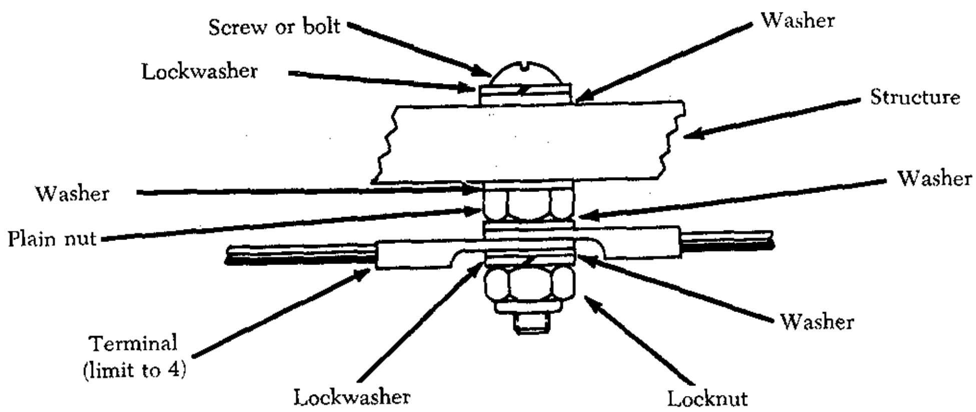


FIGURE 4–114. Stud bonding or grounding to a flat surface.

Hardware used to make bonding or grounding connections should be selected on the basis of mechanical strength, current to be carried, and ease of installation. If connection is made by aluminum or copper jumpers to the structure of a dissimilar material, a washer of suitable material should be installed between the dissimilar metals so that any corrosion will occur on the washer.

Hardware material and finish should be selected on the basis of the material of the structure to which attachment is made and on the material of the jumper and terminal specified for the bonding or grounding connection. Either a screw or bolt of the proper size for the specified jumper terminal should be used. When repairing or replacing existing bonding or grounding connections, the same type of hardware used in the original connection should always be used.

CONNECTORS

Connectors (plugs and receptacles) facilitate maintenance when frequent disconnection is required. Since the cable is soldered to the connector inserts, the joints should be individually installed and the cable bundle firmly supported to avoid damage by vibration. Connectors have been particularly vulnerable to corrosion in the past, due to condensation within the shell. Special connectors with waterproof features have been developed which may replace nonwaterproof plugs in areas where moisture causes a problem. A connector of the same basic type and design should be used when replacing a connector. Connectors that are susceptible to corrosion difficulties may be treated with a chemically inert waterproof jelly. When replacing connector assemblies, the socket-type insert should be used on the half which is "live" or "hot" after the connector is disconnected to prevent unintentional grounding.

Types of Connectors

Connectors are identified by AN numbers and are divided into classes with the manufacturer's variations in each class. The manufacturer's variations are differences in appearance and in the method of meeting a specification. Some commonly used connectors are shown in figure 4–118. There are five basic classes of AN connectors used in most aircraft. Each class of connector has slightly different construction characteristics. Classes A,

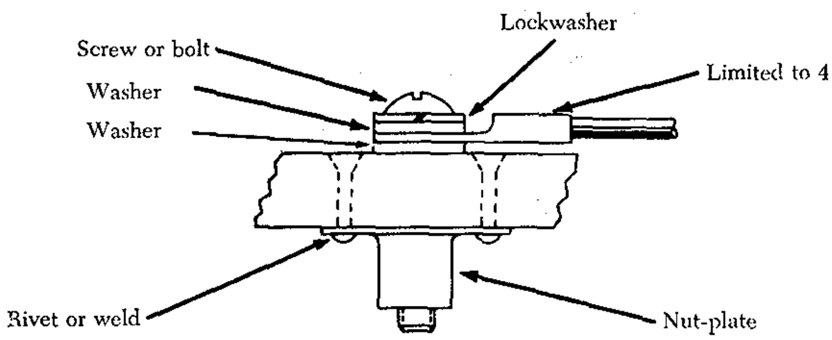


FIGURE 4–115. Nut-plate bonding or grounding to flat surface.

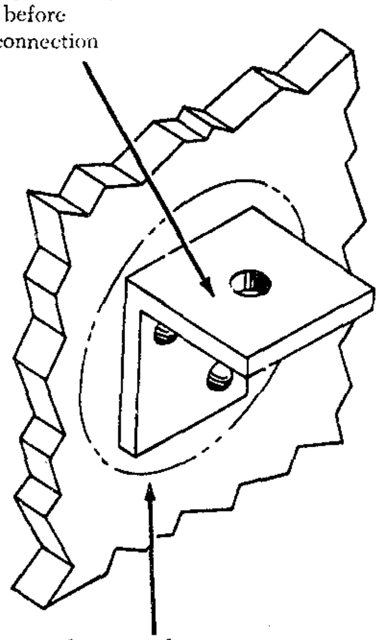


FIGURE 4–116. Bonding or grounding tab riveted to structure.

B, C, and D are made of aluminum, and class K is made of steel.

(1) Class A—Solid, one-piece back shell general-purpose connector.

(2) Class B—Connector back shell separates into two parts lengthwise. Used primarily where it is important that the soldered connectors are readily accessible. The back shell is held together by a threaded ring or by screws.

(3) Class C—A pressurized connector with inserts that are not removable. Similar to a class A connector in appearance, but the inside sealing arrangement is sometimes different. It is used on walls or bulkheads of pressurized equipment.

(4) Class D—Moisture- and vibration-resistant connector which has a sealing grommet in the back shell. Wires are threaded through tight-fitting holes in the grommet, thus sealing against moisture.

(5) Class K—A fireproof connector used in areas where it is vital that the electric current is not interrupted, even though the connector may be exposed to continuous open flame. Wires are crimped to the pin or socket contacts and the shells are made of steel. This class of connector is normally longer than other connectors.

Connector Identification

Code letters and numbers are marked on the coupling ring or shell to identify a connector. This code (figure 4–119) provides all the information necessary to obtain the correct replacement for a defective or damaged part.

Many special-purpose connectors have been designed for use in aircraft applications. These include subminiature and rectangular shell connectors, and connectors with short body shells, or of split-shell construction.

Installation of Connectors

The following procedures outline one recommended method of assembling connectors to receptacles:

(1) Locate the proper position of the plug in relation to the receptacle by aligning the key

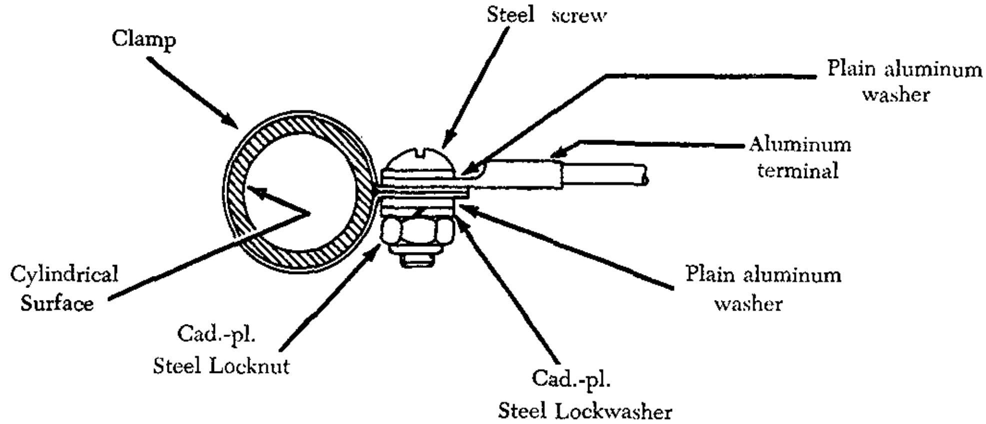


FIGURE 4–117. Bonding or grounding connections to a cylindrical surface.

FIGURE 4–118. AN connectors.

of one part with the groove or keyway of the other part.

(2) Start the plug into the receptacle with a slight forward pressure and engage the threads of the coupling ring and receptacle.

(3) Alternately push in the plug and tighten the coupling ring until the plug is completely seated.

(4) Use connector pliers to tighten coupling rings one-sixteenth to one-eighth of a turn beyond finger tight if space around the connector is too small to obtain a good finger grip.

(5) Never use force to mate connectors to receptacles. Do not hammer a plug into its receptacle, and never use a torque wrench or pliers to lock coupling rings.

A connector is generally disassembled from a receptacle in the following manner:

(1) Use connector pliers to loosen coupling rings which are too tight to be loosened by hand.

(2) Alternately pull on the plug body and unscrew

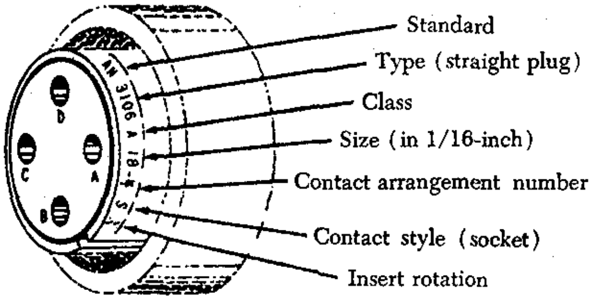


FIGURE 4–119. AN connector marking.

the coupling ring until the connector is separated.

(3) Protect disconnected plugs and receptacles with caps or plastic bags to keep debris from entering and causing faults.

(4) Do not use excessive force, and do not pull on attached wires.

CONDUIT

Conduit is used in aircraft installations for the mechanical protection of wires and cables. It is available in metallic and nonmetallic materials and in both rigid and flexible form.

When selecting conduit size for a specific cable bundle application, it is common practice to allow for ease in maintenance and possible future circuit expansion by specifying the conduit inner diameter about 25% larger than the maximum diameter of the conductor bundle. The nominal diameter of a rigid metallic conduit is the outside diameter. Therefore, to obtain the inside diameter, subtract twice the tube wall thickness.

From the abrasion standpoint, the conductor is vulnerable at the ends of the conduit. Suitable fittings are affixed to conduit ends in such a manner that a smooth surface comes in contact with the conductor within the conduit. When fittings are not used, the conduit end should be flared to prevent wire insulation damage. The conduit is supported by clamps along the conduit run.

Many of the common conduit installation problems can be avoided by proper attention to the following details:

(1) Do not locate conduit where it can be used as a handhold or footstep.

(2) Provide drain holes at the lowest point in a conduit run. Drilling burrs should be carefully removed from the drain holes.

(3) Support the conduit to prevent chafing against the structure and to avoid stressing its end fittings.

Damaged conduit sections should be repaired to prevent injury to the wires or wire bundle. The minimum acceptable tube bend radii for rigid conduit as prescribed by the manufacturer's instructions should be carefully followed. Kinked or wrinkled bends in a rigid conduit are normally not considered acceptable.

Flexible aluminum conduit is widely available in two types: (1) Bare flexible and (2) rubber-covered conduit. Flexible brass conduit is normally used instead of flexible aluminum where necessary to minimize radio interference. Flexible conduit may be used where it is impractical to use rigid conduit, such as areas that have motion between conduit ends or where complex bends are necessary. Transparent adhesive tape is recommended when cutting flexible conduit with a hacksaw to minimize fraying of the braid.

ELECTRICAL EQUIPMENT INSTALLATION

This section provides general procedures and safety precautions for installation of commonly used aircraft electrical equipment and components. Electrical load limits, acceptable means of controlling or monitoring electrical loads, and circuit protection devices are subjects with which mechanics must be familiar to properly install and maintain aircraft electrical systems.

Electrical Load Limits

When installing additional electrical equipment that consumes electrical power in an aircraft, the total electrical load must be safely controlled or managed within the rated limits of the affected components of the aircraft's power-supply system.

Before any aircraft electrical load is increased, the associated wires, cables, and circuit-protection devices (fuses or circuit breakers) should be checked to determine that the new electrical load (previous maximum load plus added load) does not exceed the rated limits of the existing wires, cables, or protection devices.

The generator or alternator output ratings prescribed by the manufacturer should be compared with the electrical loads which can be imposed on the affected generator or alternator by installed equipment. When the comparison shows that the probable total connected electrical load can exceed the output load limits of the generator(s) or alternator(s), the load should be reduced so that an overload cannot occur. When a storage battery is part of the electrical power system, ensure that the battery is continuously charged in flight, except when short intermittent loads are connected, such as a radio transmitter, a landing-gear motor, or other similar devices which may place short-time demand loads on the battery.

Controlling or Monitoring the Electrical Load

Placards are recommended to inform crewmembers of an aircraft about the combinations of loads that can safely be connected to the power source.

In installations where the ammeter is in the battery lead, and the regulator system limits the maximum current that the generator or alternator can deliver, a voltmeter can be installed on the system bus. As long as the ammeter does not read "discharge" (except for short intermittent loads such as operating the gear and flaps) and the voltmeter remains at "system voltage," the generator or alternator will not be overloaded.

In installations where the ammeter is in the generator or alternator lead, and the regulator system does not limit the maximum current that the generator or alternator can deliver, the ammeter can be redlined at 100% of the generator or alternator rating. If the ammeter reading is never allowed to exceed the red line, except for short, intermittent loads, the generator or alternator will not be overloaded.

Where the use of placards or monitoring devices is not practicable or desired, and where assurance is needed that the battery in a typical small aircraft generator/battery power source will be charged in flight, the total continuous connected electrical load may be held to approximately 80% of the total rated generator output capacity. (When more than one generator is used in parallel, the total rated output is the combined output of the installed generators.)

When two or more generators are operated in parallel and the total connected system load can exceed the rated output of one generator, means must be provided for quickly coping with the sudden overloads which can be caused by generator or engine failure. A quick load-reduction system can be employed or a specified procedure used whereby the total load can be reduced to a quantity which is within the rated capacity of the remaining operable generator or generators.

Electrical loads should be connected to inverters, alternators, or similar aircraft electrical power sources in such a manner that the rated limits of the power source are not exceeded, unless some type of effective monitoring means is provided to keep the load within prescribed limits.

Circuit Protection Devices

Conductors should be protected with circuit breakers or fuses located as close as possible to the electrical power-source bus. Normally, the manufacturer of the electrical equipment specifies the fuse or circuit breaker to be used when installing the equipment.

The circuit breaker or fuse should open the circuit before the conductor emits smoke. To accomplish this, the time/current characteristic of the protection device must fall below that of the associated conductor. Circuit-protector characteristics should be matched to obtain the maximum utilization of the connected equipment.

Figure 4–120 shows an example of the chart used in selecting the circuit breaker and fuse protection for copper conductors. This limited chart is applicable to a specific set of ambient temperatures and wire bundle sizes, and is presented as a typical example only. It is important to consult such guides before selecting a conductor for a specific purpose. For example, a wire run individually in the open air may be protected by the circuit breaker of the next higher rating to that shown on the chart.

All re-settable circuit breakers should open the circuit in which they are installed regardless of the position of the operating control when an overload or circuit fault exists. Such circuit breakers are referred to as "trip-free." Automatic re-set circuit breakers automatically re-set themselves periodically. They should not be used as circuit protection devices in aircraft.

Switches

A specifically designed switch should be used in all circuits where a switch malfunction would be

Wire AN gauge copper	Circuit breaker amperage	Fuse amp.
22	5	5
20	7.5	5
18	10	10
16	15	10
14	20	15
12	30	20
10	40	30
8	50	50
6	80	70
4	100	70
2	125	100
1		150
0		150

FIGURE 4–120. Wire and circuit protector chart.

hazardous. Such switches are of rugged construction and have sufficient contact capacity to break, make, and carry continuously the connected load current. Snap-action design is generally preferred to obtain rapid opening and closing of contacts regardless of the speed of the operating toggle or plunger, thereby minimizing contact arcing.

The nominal current rating of the conventional aircraft switch is usually stamped on the switch housing. This rating represents the continuous current rating with the contacts closed. Switches should be derated from their nominal current rating for the following types of circuits:

(1) High rush-in circuits—Circuits containing incandescent lamps can draw an initial current which is 15 times greater than the continuous current. Contact burning or welding may occur when the switch is closed.

(2) Inductive circuits—Magnetic energy stored in solenoid coils or relays is released and appears as an arc as the control switch is opened.

(3) Motors—Direct-current motors will draw several times their rated current during starting, and magnetic energy stored in their armature and field coils is released when the control switch is opened.

The chart in figure 4–121 is typical of those available for selecting the proper nominal switch rating when the continuous load current is known. This selection is essentially a derating to obtain reasonable switch efficiency and service life.

Nominal system Voltage	Type of load	Derating factor
24 V.D.C.	Lamp	8
24 V.D.C.	Inductive (Relay-Solenoid)	4
24 V.D.C.	Resistive (Heater)	2
24 V.D.C.	Motor	3
12 V.D.C.	Lamp	5
12 V.D.C.	Inductive (Relay-Solenoid)	2
12 V.D.C.	Resistive (Heater)	1
12 V.D.C.	Motor	2

FIGURE 4–121. Switch derating factors.

Hazardous errors in switch operation can be avoided by logical and consistent installation. Two position "on-off" switches should be mounted so that the "on" position is reached by an upward or forward movement of the toggle. When the switch controls movable aircraft elements, such as landing gear or flaps, the toggle should move in the same direction as the desired motion. Inadvertent operation of a switch can be prevented by mounting a suitable guard over the switch.

Relays

Relays are used as switching devices where a weight reduction can be achieved or electrical controls can be simplified. A relay is an electrically operated switch and is therefore subject to dropout under low system voltage conditions. The foregoing discussion of switch ratings is generally applicable to relay contact ratings.